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SEWER AND SEWAGE TREATMENT PLANT CONSTRUCTION COST INDEX

Federal Water Pollution Control Administration
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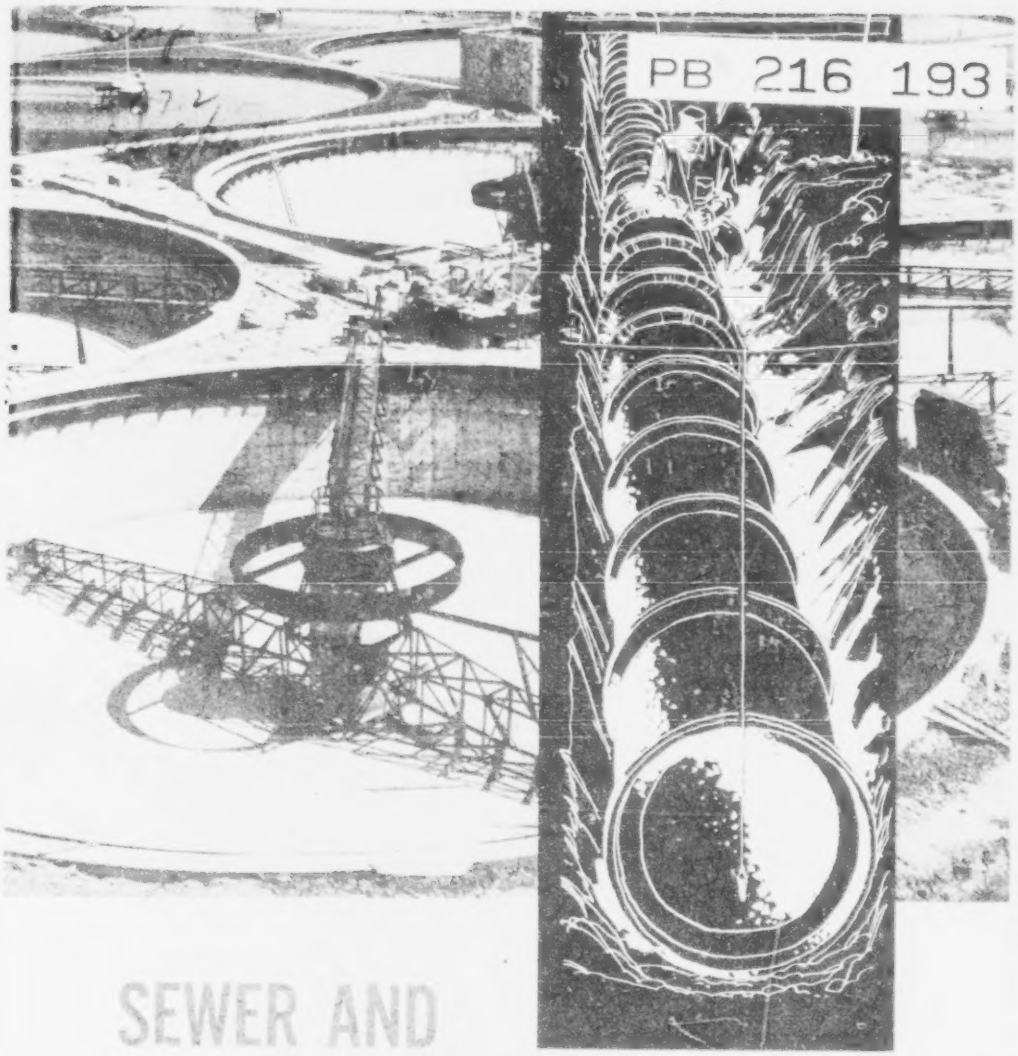

SEWER AND SEWAGE TREATMENT PLANT CONSTRUCTION COST INDEX

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CWT - 1 December, 1967

SEWER AND SEWAGE TREATMENT PLANT CONSTRUCTION COST INDEX

CONSTRUCTION COST TRENDS
MUNICIPAL WASTE TREATMENT WORKS
AND
MUNICIPAL SEWERS

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
DIVISION OF CONSTRUCTION GRANTS
WASHINGTON, D. C. 20242

contents

Foreword ---------- iv

PART ONE
SEWAGE TREATMENT PLANT
CONSTRUCTION COST INDEX

Introduction ---------- 2
Background ---------- 3
Need for Index ---------- 4
Assumptions and Base Data for Index 6
Development of the Cost Index ------ 9
Computation of National Index ----- 13
Computation of Individual City Index 14
Discussion ---------- 14
Conclusions ---------- 15
References ---------- 16

PART TWO
SEWER CONSTRUCTION
COST INDEX

Introduction ---------- 18
Background ---------- 19
Assumptions and Base Data for the Index ---------- 20
Development of Cost Index --------- 23
Computation of National Index ----- 29
Computation of Individual City Index 30
Discussion ---------- 30
Conclusions ---------- 33
References ---------- 34

appendices

A. Map of 20 Index Cities and Their Assigned Areas of Influence 36

B. Design Data for a 1.0-MGD High Rate Trickling Filter Plant 37

C. Material and Labor Costs Analysis of the Construction Categories for a 1.0-MGD High Rate Trickling Filter Plant at Kansas City, Mo., August 1, 1962 (table) 40

D. Total Plant and Categroy Costs for 20 Index Cities (table) 42

E. Sewage Treatment Plant Process Equipment — Manufacturers' Composite Experience Curve and FWPCA Process Equipment Index Curve (chart) 44

F. Cost Curves by Categroy for a 1.0-MGD High Rate Trickling Filter Plant, Kansas City, Mo., August 1930–62 (1957–59=100) 45

G. Municipal Waste Treatment Plant Cost Indexes 46

H. Municipal Waste Treatment Plant Cost Indexes (charts) 48

I. Material and Labor Cost Analysis of the Construction Categories for a $1 Million Hypothetical Sewer Project at Kansas City, Mo., August 1, 1962 (table) 50

J. Sewer Pipe Cost Relationships (parts 1 and 2) 52

K. Total Sewer Project Costs for 20 Index Cities (table) 54

L. Sewer Construction Cost Indexes (table) 56

M. Individual City Indexes and National Index (charts) 58

foreword

Construction costs for sewers and treatment plants have risen steadily since the mid 1930's. Rates of increase vary among the different construction elements such as labor, materials and equipment, as well as for different types of construction.

Contract award data have proven useful for evaluating progress in the construction of sewers and treatment plants. The data has also been valuable in estimating future construction requirements for the prevention and control of water pollution.

During a period of rising costs, however, such data need to be adjusted to a standard base to assure comparability. This can be done through the use of an appropriate construction cost index.

In 1961, the Division of Construction Grants of the Federal Water Pollution Control Administration (then the Division of Water Supply and Pollution Control of the Department of Health, Education, and Welfare) undertook to design cost indexes for both municipal sewage treatment plant and sewer construction, since none existed specifically for these types of construction.

With expert help from both in and outside of Government, the sewage treatment plant construction cost index was developed and published in 1963, as Public Health Service Publication No. 1069. The sewer construction cost index was published in 1964 as Public Health Service Publication No. 1132.

Originally designated the PHS-STP and the PHS-S indexes, they will be now known as the WPC-STP index for treatment plant construction costs and the WPC-S index for sewer construction costs. Monthly summaries continuously updating both indexes are prepared by the Division of Construction Grants, Federal Water Pollution Control Administration.

PART ONE

Sewage Treatment Plant Construction Cost Index

introduction

Grants-in-aid for municipal waste treatment works construction were first authorized under the Federal Water Pollution Control Act of 1956 and widely liberalized by the Congress in the decade which followed. Commensurately, the dollar volume of construction contracts awarded for these facilities has steadily increased. To accurately assess this increase insofar as it relates to progress in water pollution control, and to estimate the future needs, calls for a thorough understanding of the changing purchasing power of the local and Federal funds invested in municipal waste treatment works. These were among the objectives in the Federal Water Pollution Control Administration's development of the sewage treatment plant construction cost index as here presented. Several existing cost indexes were examined in the process and are discussed in a portion of this report.

A price or cost index number is the ratio of the sum of the prices or costs of a product or service in a given period divided by the sum of the prices or costs for similar products or services for a base period (*1*). A price index differs from a cost index in that a price index is influenced by the prices of factors, whereas a cost index is influenced by prices and quantities of factors entering the "standard product" at two different periods. More specifically, a

$$\text{Construction Price Index} = \frac{P_{1_a}+P_{2_a}+P_{3_a}+\cdots P_{n_a}}{P_{1_b}+P_{2_b}+P_{3_b}+\cdots P_{n_b}}\times 100 = \frac{\sum P_a}{\sum P_b}\times 100 \qquad (1)$$

where

P_1, P_2, $P_3 + \cdots P_n$ are prices of the factors making up a "standard product" of construction, "a" is any given construction period, and "b" is the base period of construction; and a

$$\text{Construction Cost Index} = \frac{P_{1_a}Q_{1_a}+P_{2_a}Q_{2_a}+P_{3_a}Q_{3_a}+\cdots P_{n_a}Q_{n_a}}{P_{1_b}Q_{1_b}+P_{2_b}Q_{2_b}+P_{3_b}Q_{3_b}+\cdots P_{n_b}Q_{n_b}}\times 100 = \frac{\sum P_aQ_a}{\sum P_bQ_b}\times 100 \qquad (2)$$

where

$P_1, P_2, P_3 + \cdots P_n$, and "a" and "b" are the same as in equation (1) and Q_1, Q_2, $Q_3 + \cdots Q_n$ are the quantities of the factors making up a "standard product" of construction.

The "standard product" of construction in this development is a sewage treatment plant of fixed design and specifications, combined in proper proportion to represent the series evaluated. The factors entering are: skilled and common labor, construction materials, process equipment, construction equipment, and overhead and profit.

A cost index may either be a "floating base" type or a "fixed base" type (*2*). The "floating base" refers to a quantity variable; i.e., the quantity (Q) factors may vary from period to period with the price (P) factors either increasing or decreasing due to internal or external causes. The "fixed base" index has constant quantity factors; i.e., there is no change in the quantity (Q) factors from period to period and consequently the cost may vary due to external causes only. Indexes of each base type are common.

This report deals with the development of a fixed base, weighted, cost index, which is believed to be a substantially accurate indication of the purchasing power of funds invested in sewage treatment plant construction. A reliable measure of the relative purchasing power of money may be obtained by evaluating the changing unit prices of comparable commodities in which an industry deals.

background

In its broad and generic meaning, an index number is an average of relatives or variations. If the variations measured are those of commodity prices, an index of prices is obtained: index numbers of wages, interest rates, profits, production, and a large number of other measurable phenomena also have been computed. Each of the applications of index numbers may be subject to peculiarities of its own; and, in every case, the average is drawn for the specific purpose for which it can appropriately be used.

Index numbers were first used to measure the rise or fall of prices, i.e., the inverse movement of the general exchange value of money; and the term itself was coined in this connection. In 1838 Porter used the term "index prices," and in 1869 the *London Economist* (*2*) called the sum of the relatives of 22 prices, which it compiled, the "total index number." The term "index number" quickly came into common usage to denote the prices of individual commodities averaged at each period, their total sum, or an average of them—this last meaning being the most popular.

A price index number, whether it relates to all prices, or merely to those of a single commodity group, is a series of averages for price distribution at successive dates. As such, it measures only the change in the general tendency of the distribution. It fails to reveal the

changes in their internal structure and conceals changes which may reflect on the reliability of the index number as a representative value. Only within the last several decades has attention been centered on these aspects of changing prices. Previously, the complex variations in the internal price structure, which are of vast economic significance, were apt to be regarded merely as troublesome obstacles to the calculation of reliable averages.

History reveals that price indexes fail to reflect the changes in internal structure, such as technological advances, progressive improvements in business organizations, and changes in the prices of the various elements of production, all of which may result in increasing output being accompanied by decreasing money costs.

Economically, "cost" means the surrender or destruction of value, or the performance of some irksome activity as a means of production of commodities or the acquisition of income. The classical school gives three rival explanations of cost; namely, (1) psychological or pain costs, (2) labor costs, and (3) money costs, or, expenses of production (*3*). Construction cost encompasses all these philosophies and includes materials, machines, men, and money. More specifically, construction cost is equal to the sum of the cost of:

(1) Materials = concrete, lumber, iron, steel, etc., used in construction;
(2) Machines = process equipment and contractor's equipment used in construction;
(3) Men = skilled and common (heavy construction) labor employed during construction; and
(4) Money = overhead charged and profit earned during construction.

or,

$$\text{Construction cost} = M_1 + M_2 + M_3 + M_4 \qquad (3)$$

need for index

A review of the several general-purpose construction cost indexes, such as those of American Appraisal Co., Associated General Contractors, E. H. Boeckh & Associates, Marshall & Stevens, and *Engineering News-Record* (ENR), disclosed no adequate basis for assuming that any of these accurately measure the changing cost of waste treatment plant construction due to weight and/or price bias. From a practical standpoint, though, an index such as the ENR Construction Cost Index (*4*) has certain advantages. It is well known, simple, and fairly well understood—having been used for some time in the construction industry (calculated back to the year 1903). This index

was established in 1921 to diagnose and track the wild fluctuations in prices after World War I. The quantity factors are:

(1) 200 hours of common labor (including fringe benefits),
(2) 25 CWT of structural steel,
(3) 1.088 Mbf of 2 by 4's S4S lumber,
(4) 6 barrels of cement.

This gives a rudimentary idea of the cost of building materials used in general heavy construction as well as the cost of common labor. In addition, the ENR Construction Index is published monthly over a fairly broad base, using data from 20 selected cities. The disadvantages of this index with respect to sewage treatment plant construction are:

(1) It does not include the most important commodities used (process equipment and skilled labor) in this type of construction—a quantity bias.
(2) It does not represent materials cost-in-place or even on the job, which could differ substantially from the wholesale prices of these same materials—a price bias.
(3) It uses a weighting that is not representative of modern design and construction practices—a weight bias.

The development of a satisfactory index requires the elimination of all or as many as possible of the disadvantages inherent in existing indexes; namely, the quantity, weight, and price biases. A new index must also be comparable throughout the required period in which comparisons are to be made. Continuity for former periods can only be maintained by calculating backward in time and there are many reasons why this is sometimes not possible. The labor rates involved constitute an important reason, especially where the series is long or where there have been several changes in the components of the index. In addition, the original data used in computations years ago may not be readily available, requiring time and resources to assemble. Sometimes such data are not available.

There are two possibilities which might be investigated for the elimination or reduction of the biases inherent in available indexes. The first would necessitate the use of part of the various general construction index data (*5, 6, 7, 8*) and/or primary data from other sources, e.g., Department of Commerce Reports, Bureau of Labor Statistics (BLS) Reports, and business and government magazines or journals, to construct, by estimating quantity and weight parameters, an index number for sewage treatment plant construction. This alternative would require that the quantities and weights be estimated and there is considerable uncertainty as to the accuracy with which this could be done.

The second alternative, the one developed herein, is the construction

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of an econometric model from real prices and quantities for a statistically representative sewage treatment plant utilizing published price data that are available for the period investigated. Theoretically, this is the best method to pursue, for the index does reflect the true quantities it represents. Furthermore, this index has the obvious advantage of being its own test for the base period. Having a fixed base, surveys could be made from time to time to see if the base still reflects sewage treatment plant construction practice. This method will provide a good measuring stick to study the trends and magnitude of sewage treatment plant construction in constant dollar values.

assumptions and base data for index

In the development of this construction cost index for sewage treatment plants, designed as a fixed base, weighted index, certain assumptions were made:

1. The hourly output of labor remains constant in spite of changing wage rates. That is, when the wage rates rise (or fall) because labor supply lags behind (or exceeds) demand, the hourly output of labor is assumed to remain constant.
2. The quantities and kinds of materials used will remain constant and available during the periods under study.
3. Modern treatment plant construction techniques date back to the year 1930.

Within the limitations of these assumptions, the index may be used for (*a*) estimating construction and equipment costs at various dates; (*b*) checking present costs with costs for similar work during previous years; (*c*) verifying other cost data; and (*d*) forecasting future cost trends.

Weighting

This index does not reflect the cost of land; engineering, legal, and fiscal services; and errors, omissions, and changes subsequent to contract award. It does include the following "indicators" that are common to sewage treatment works: (*a*) cost of materials, (*b*) cost of process equipment, (*c*) construction labor cost, (*d*) contractor's plant costs (contractor's equipment), and (*e*) overhead and profit. Process equipment is peculiar to sewage treatment works.

Base Period

In order to provide a comparable base to other Federal indexes, the

36-month period January 1, 1957, through December 31, 1959, was selected as a base for this index. This time period conforms to the postwar base period for Federal Index numbers as defined by the Bureau of the Budget.

Geographical Locations

Prices of materials and services vary considerably throughout the country. An index based on average prices and costs (countrywide) would not necessarily be acceptable for local or regional use. Consequently, regional indexes are necessary for each of the country's major commercial marketing areas for which price data are available (*9*). These areas, separated on a county line basis, represent areas of influence for each of the following 20 trade centers:

Atlanta, Ga.	Dallas, Tex.	New York, N.Y.
Baltimore, Md.	Denver, Colo.	Philadelphia, Pa.
Birmingham, Ala.	Detroit, Mich.	Pittsburgh, Pa.
Boston, Mass.	Kansas City, Mo.	St. Louis, Mo.
Chicago, Ill.	Los Angeles, Calif.	San Francisco, Calif.
Cincinnati, Ohio	Minneapolis, Minn.	Seattle, Wash.
Cleveland, Ohio	New Orleans, La.	

These trade centers are those for which *Engineering News-Record* publishes monthly price data. The national index is based on the sum of the cost of identical plants built in each of the 20 city areas. A map showing the 20 cities and their assigned areas of influence is to be found in appendix A.

Design Characteristics of Model Plant

An analysis of contract awards for sewage treatment plants, assisted under the Federal Water Pollution Control Act during the period 1956 through 1962, revealed an average hydraulic capacity of 1.34 million gallons daily (MGD), a design population of 12,000, and a contract cost of $40 per capita (*10, 11*). The most frequent treatment process was the high rate trickling filter. This information was to provide the basis for the design of a hypothetical plant, but since there is very little difference in the physical size of the structural components or hydraulic requirements of a 1.34-MGD and a 1.0-MGD high rate trickling filter plant, a 1.0-MGD plant was used as the model for the cost index. Since various types of sewage treatment plants are now being constructed, allowances were made to incorporate unique units in the model plant in order that the index would be valid for all types of municipal waste treatment works. The cost estimate of this plant was predicated on idealized conditions, representing minimal costs under circumstances prevailing in Kansas City, Mo.,

in August 1962. Design data and a layout of the plant are included in appendix B. Design characteristics are as follows:

General. The plant was designed for a population of 10,000 people, an average flow of 1.0 MGD, a maximum flow of 2.5 MGD, a biological oxygen demand (BOD) of 200 mg/l, a recirculation ratio of 1½ to 1, and an overall BOD reduction of 92 percent.

The plant includes a comminutor, with a bar screen serving as a bypass device, Parshall flume, preaeration tank with grit removal, primary sedimentation tanks, a settled sewage pumping station with provision for recirculation, high rate trickling filters, secondary sedimentation tank, chlorine contact tank, primary and secondary digesters, and a sludge filter building which also contains an office and laboratory. Sludge drying beds are provided as an auxiliary feature. Facilities to allow for prechlorination and postchlorination are also provided.

Flow Through the Plant. The plant flow is divided into the following segments:

(1) By gravity through the comminutor, Parshall flume, preaeration tanks, and primary sedimentation tanks;

(2) By pumping from the wet well following the primary sedimentation tanks to a distribution box for gravity application to the trickling filters; and

(3) By gravity from the trickling filters to the secondary sedimentation tank, recirculation structure, chlorine contact tank, and to the outfall sewer.

Recirculation of Flow. Recirculation of plant flow is accomplished by a pneumatically operated valve and piping system connecting the recirculation structure with the wet well of the pumping station. The operation of this valve is automatically controlled by the sewage level in the pumping station wet well using an air bubbler system.

Sludge collected in the primary sedimentation tanks is pumped to the digester and sludge from the secondary sedimentation tank is recirculated, by pumping, to the aerated grit chambers.

Bypass Connections. Provision for bypassing is provided as follows:

(1) Between the comminutor and the Parshall flume,

(2) From the wet well of the pumping station,

(3) Between the trickling filters and the secondary sedimentation tank, and

(4) From the recirculation structure.

Maintenance. Separate drains are provided in each of the basins to allow for cleaning and maintenance. The piping and layout of the aerated grit chambers and primary sedimentation tanks are arranged

so that any combination of these chambers and tanks can be removed from service.

Other. Provision is made for doubling the capacity of the plant. All utilities are available at the plant site.

development of cost index

Category Assignment

To develop the cost index it was necessary to consider the various major categories of a construction job, in this instance the hypothetical treatment plant. The construction categories were assigned as follows:

A. Excavation and fill,
B. Reinforced concrete,
C. Miscellaneous iron and steel,
D. Pipe, valves, and fittings,
E. Process equipment, pumps, and motors,
F. Sand and rock for filter media and drying bed fill,
G. Buildings, and
H. Other items.

As stated earlier, the costs of land; engineering; legal and fiscal services; and errors, omissions, and changes subsequent to contract award are not included since the index is predicated on a contract cost basis. For the purpose of estimating these excluded items, an allowance of 20 percent of contract cost can be used.

Basis for Unit Construction Cost. To obtain the unit construction costs for the model plant, it was necessary to determine quantities of material and labor required to build the plant. This was done by a quantity analysis of materials and labor for the model plant, utilizing prices and wages prevailing in the Kansas City area during August 1962, as locally reported.

Unit Prices for Material and Labor. To provide for a continuing pricing basis, the estimated material prices and labor wages ascertained by the study of data from the Kansas City area were compared with the corresponding prices and wages reported by *Engineering News-Record* to be prevailing in Kansas City, Mo., during August 1962. Where differences were found, the ENR unit value prevailed and the quantity of the unit was adjusted to produce the predetermined dollar value for the component. This caused a slight modifi-

cation in design quantities. The modified design quantities were used with the reported unit prices for each of the 20 cities included in this report. Appendix C lists the various materials and labor that comprise these components for each category of construction of the model plant.

Process Equipment. Process equipment required a unique approach, as an analysis of the literature, manufacturers' catalogs and brochures, and discussions with consulting engineers disclosed no standardized units of weights or measures as well as no continuing published pricing data. Since it was found that the process equipment (category E) amounts to approximately $156,000, or 34 percent of the total plant construction cost, it became necessary to establish a common frame of reference which could be priced on a continuing basis from regularly reported unit prices.

Consultation with equipment manufacturers disclosed that process equipment factory prices closely follow the production cost of the following combination of materials with an equal allowance for labor:

	Percent
Steel and machine products	90
Castings and forgings	10

The process equipment factory prices, however, are f.o.b. point of manufacture and do not include freight, royalties, resale, and the other after plant costs. The BLS (*12*) wholesale prices, which include these after plant costs, were selected for use with this category as follows:

Structural Steel Shapes—for steel and machine products,
and
Pig Iron, No. 2, Foundry—for casting and forgings.

An index curve was developed using these materials in the previously defined ratio for the process equipment based on the BLS wholesale prices. This curve was submitted to the manufacturers for comparison and comment. In practically every instance, the index curve was in close agreement with the manufacturers' experience. This is demonstrated graphically in appendix E.

Construction Component Costs

The following fundamental components are normally used in cost analyses of construction work: (*a*) material, (*b*) labor, (*c*) contractor's plant costs, and (*d*) overhead and profit. Since material, labor, and contractor's plant cost data were available for the model plant, these components were used as a starting point in developing the

cost index. The fourth component, overhead and profit, was estimated on a percent basis of the three preceding determinate values. The allowance for overhead and profit was obtained by using approximately 15 percent of material costs, 15 percent of contractor's plant costs, and 25 percent of the labor cost.

The table on page 12 shows the component costs for the eight construction categories used in the development of the index.

The following assumptions and explanations refer to the categories in the table:

1. It was assumed that the materials used for forms and shoring for reinforced concrete could be used three times.
2. Category (F), Sand and Rock, includes only the filter media of the trickling filters and the sand fill of the sludge drying beds.
3. Category (G), Buildings, includes the cost of concrete block, brick, doors, windows, etc., but does not include framing costs which are included under iron and steel or reinforced concrete.
4. Category (H), Other Items, includes the costs of plumbing, heating and ventilating, electrical and other items.

Category Division

A review of several studies (*13*, *14*, *15*, *16*, *17*, *18*, *19*) made on the construction cost of sewage treatment plants revealed that materials are, indeed, the chief cost ranging from 48 to 74 percent for all types of plants, and between 54 and 66 percent for trickling filter plants. Labor ranged from a low of 20 percent to a high of 29 percent, and the "other" (contractor's plant, overhead and profit, etc.) ranged from a low of 16 percent to a high of 19 percent. The distribution of construction cost for the hypothetical plant shown in the table is in close agreement with these findings.

Computation of Total Category Cost

Since material and labor unit prices are the only cost values historically available in published form, it became necessary to express contractor's plant, overhead, and profit as a fixed percent of the labor and material cost. These percent values were determined from the estimated costs for these items as reported for the model plant (table, p. 12). This was done for each construction category in five steps as follows:

For Category A—August 1962:

(1) Material plus labor cost = $18,555.43

= 42.83 percent of total category cost

Construction Categories, Components, Costs and Percent of Costs for a 1.0 High Rate Trickling Filter Plant (Kansas City, Mo.—August 1962)

Construction category	Material cost		Labor cost		Contractor's plant		Overhead and profit		Total category cost	
	Dollar value	Percent of category	Dollar value	Percent of category	Dollar value	Percent of category	Dollar value	Percent of category	Dollar value	Percent of plant
A. Excavation and Fill	$7, 370. 99	17. 01	$11, 184. 44	25. 82	$18, 144. 91	41. 88	$6, 615. 28	15. 28	$43, 315. 62	9. 376
B. Reinforced Concrete	49, 295. 33	43. 91	41, 837. 98	37. 27	3, 874. 41	3. 45	17, 287. 97	15. 40	112, 259. 59	24. 297
C. Miscellaneous Iron and Steel	6, 542. 64	51. 13	3, 993. 05	31. 20	249. 52	1. 95	2, 010. 93	15. 71	12, 796. 14	2. 770
D. Pipes, Valves, and Fittings	26, 241. 57	56. 51	13, 244. 17	28. 52	1, 030. 31	2. 22	5, 922. 53	12. 75	46, 438. 58	10. 051
E. Process Equipment, Pumps and Motors	118, 659. 63	75. 92	14, 409. 93	9. 22	3, 766. 59	2. 41	19, 453. 79	12. 44	156, 289. 94	33. 826
F. Sand and Rock	9, 259. 18	52. 62	4, 631. 26	26. 32	1, 002. 99	5. 70	2, 702. 96	15. 36	17, 596. 39	3. 808
G. Buildings	6, 167. 23	43. 40	6, 533. 50	45. 98	150. 61	1. 06	1, 359. 30	9. 57	14, 208. 74	3. 075
H. Other Items	28, 241. 31	47. 76	21, 221. 74	35. 89	1, 580. 75	2. 67	8, 085. 49	13. 67	59, 129. 29	12. 797
T. Total Plant	251, 777. 88	54. 49	117, 055. 97	25. 33	29, 800. 09	6. 45	63, 440. 25	13. 73	462, 034. 29	100. 000

(2) Contractor's plant cost = $18,144.91
= 41.88 percent of total category cost

(3) Material plus labor plus contractor's plant cost = $36,700.34
= 84.71 percent of total category cost

(4) Overhead and profit cost = $6,615.28
= 15.28 percent of total category cost

(5) Total category cost for excavation and fill = $43,315.62
= 100 percent of total category cost

Extending Unit Prices To Obtain Total Material and Labor Cost. Unit prices were multiplied by the total quantity factors to determine the total quantity cost for each item. These total quantity costs were then combined to yield total category costs for construction in terms of material and labor. This is illustrated for each category in appendix C for the Kansas City, Mo., area.

The combined labor and material cost for each category was then increased by the appropriate percent values, allowing for contractor's plant, and overhead and profit, to obtain the total category cost. This procedure was followed for each of the 20 cities over the entire period of this study, using unit prices prevailing in each location. The sum of these total category costs for a given time determines the total plant construction cost for that period.

computation of national index

The first step in computing the national index was to determine the average plant cost for each of the 20 cities over the base period from January 1957 through December 1959. The sum of these 20 average values is the base for the index and equals 100.

The national index for any period is the ratio of the sum of the 20 cities' plant costs for that period, to the sum of 20 cities' average plant costs for the base period, multiplied by 100.

For example, the national index for August 1962 was calculated as follows:

Sum of the 20 cities' plant costs for August 1962 = $9,552,556.78
Sum of the 20 cities' average plant costs for base period = $8,928,457.60

$$\text{National index} = \frac{\$9,552,556.78}{\$8,928,457.60} \times 100 = 106.99$$

computation of individual city index

The plant index was determined for each city by substituting individual city total plant cost in the index formula. The base period plant cost is the sum of the average plant costs for the base period divided by 20. The ratio of the particular city's plant cost to the base period cost yields the city index. For August 1962:

Base period average plant cost = $446,422.88
Kansas City plant cost = $462,034.29

$$\text{Kansas City index} = \frac{\$462{,}034.29}{\$446{,}422.88} \times 100 = 103.49$$

The various category costs and plant costs for the 20 cities for the base period are included as appendix D. A graphic presentation of these costs (and indexes) for the Kansas City, Mo., area are included in appendix F.

Price data for each of the 20 cities for the month of August for the years beginning in 1930 were extracted from the ENR index and the BLS wholesale prices. Where these sources did not cover the entire range of time, interpolation was used based upon similarity of trades or materials at the commencement of the series. This was done primarily for labor values in the early 1930's. Electronic data processing equipment was used to calculate the individual city indexes and the national index for each year.

Plant indexes for each of the 20 cities, and the national index for the month of August are tabulated in appendixes G & H. These indexes will be extended on a monthly basis from current price data published by *Engineering News-Record* and the BLS wholesale prices.

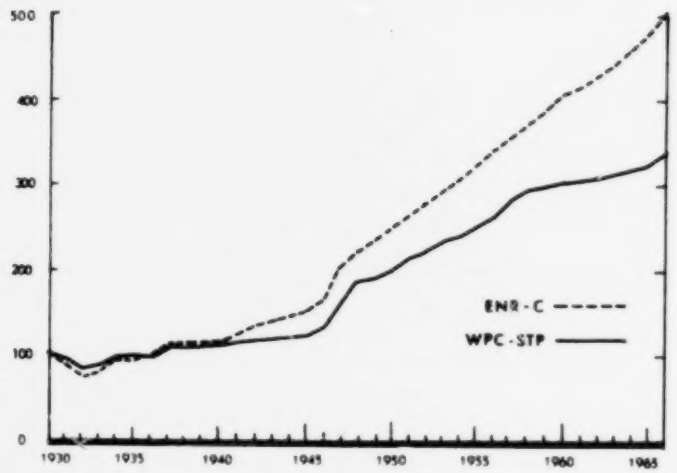
discussion

Since waste treatment works have generally been considered to follow the ENR Construction Cost Index, a comparison of this index to the Federal Water Pollution Control Administration Sewage Treatment Plant (WPC–STP) Construction Cost Index was undertaken.

In order to compare the indexes, both were converted to a base of 1930=100. The converted WPC–STP Index is included in appendix G and is shown graphically in the following figure, along with the converted ENR–C Index.

Only during 1930–40 did the two indexes follow a similar path. Since 1940 there has been a widening divergence between the WPC–STP Index and the ENR C Index. Based on 1930=100, these indexes

SEWAGE TREATMENT PLANT CONSTRUCTION COST INDEXES 1930=100



in 1966 were 503.3 for ENR–C and 339.5 for the WPC–STP Index.

A comparison of the years 1956–1966 disclosed that the ENR–C Index has increased at a rate about twice as great as the WPC–STP Index. This period of time coincides with the period of increased activity in the municipal waste treatment works construction field.

Because the WPC–STP Index is based on information peculiar to sewage treatment plant construction, its value for this specialized field is believed to be much greater.

To insure that the WPC–STP Index continues to reflect current practice in the sewage treatment plant construction industry, revaluation of the index base will be undertaken at intervals of about 10 years. Alteration, revision, or modification of the index may be required by changes in amount and/or kinds of materials, new developments, or uses of process equipment. Changes in construction methods and techniques will also be considered in each revaluation.

conclusions

(1) Comparison of the WPC–STP Construction Cost Index with the narrow-based, but widely accepted, ENR Construction Cost Index disclosed that there were substantial differences.

(2) The WPC–STP Index is believed to be representative of cost changes peculiar to municipal sewage treatment plant construction.

(3) The study shows that although sewage treatment plant con-

struction costs have increased steadily during the last 36 years.

(4) This index may be used to evaluate past construction activity and to estimate future sewage treatment plant construction cost requirements for the 20 areas of influence in the United States as well as for the Nation as a whole.

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PART TWO

Sewer Construction Cost Index

introduction

During the period 1956-66 there was a marked increase in the amounts invested in the United States for municipal sewage collection and disposal systems. Currently, about one billion dollars annually is being spent for the construction of municipal sewers; including collector, interceptor, outfall and pumping facilities, plus related appurtenances. Continued growth in sewer construction is anticipated over the next decade, in view of the backlog of needed sewer facilities and the increasing requirements associated with an expanding urban population. Estimates indicate that 588 million feet of sewer pipe will be needed by the year 1972 to meet these needs (*1*).

The growth in sewer construction is directly related to the Federal Water Pollution Control Act of 1956, as amended, which is administered by the Division of Construction Grants, FWPCA. One objective of this program is to encourage municipalities to undertake the construction of needed waste treatment works including interceptor and outfall sewers through the medium of incentive grants. A realistic assessment of the increased sewer construction activity and estimate of future construction needs require a sound appraisal of the changing purchasing power of the funds invested in this type of construction. A common denominator in the form of a valid construction cost index is indicated.

The several existing indexes were developed either for general broad fields of activity or for specific narrow uses. When applied to sewer construction, they fail to reflect fully the changes and variations in costs over the years, due either to a weight or price bias, or both. Typical examples of weighted biases appearing in existing indexes are the exclusion of skilled labor, common labor, or basic construction materials. Price bias is demonstrated in other indexes by the use of a figure based on a single supplier, in a specific geographic location, rather than the general prices prevailing in that area or areas. Some of the existing indexes are those prepared by the American Appraisal Company (*2*), the Associated General Contractors (*3*), E. H. Boeckh & Associates (*4*), Marshall and Stevens (*5*), and *Engineering News-Record* (*6*).

As a first step in obtaining an accurate appraisal of costs in the sewerage field, the Sewage Treatment Plant Construction Cost Index (*7*) was developed. It soon became evident, however, that there were vast differences in quantities of material, men, and equipment required for sewer construction, as compared with plant construction,

and that a second index designed specifically for sewer construction was necessary. This report develops and presents such an index.

background

Sewers are defined as the series of pipes and conduits including necessary appurtenances that collect and carry sewage from its point of origin (residences, business buildings, industrial institutions, etc.) to the point of final discharge, excluding building sewers and treatment facilities. This definition includes combined sewers, but excludes separate storm sewers.

The Sewer Construction Cost Index herein developed is designed to measure the rise and fall of costs for the specific commodity "sewer construction." It is the ratio of construction cost, at a specific time, to a base period construction cost.

Part one, *Sewage Treatment Plant Construction Cost Index*, discusses the relationship between price and cost index numbers and develops in detail the construction cost index. The construction cost index is defined as follows:

$$\text{Construction Cost Index} = \frac{(P_1Q_1 + P_2Q_2 + \cdots P_nQ_n)_a}{(P_1Q_1 + P_2Q_2 + \cdots P_nQ_n)_b} \times 100 = \frac{\sum P_aQ_a}{\sum P_bQ_b} \times 100 \quad (1)$$

$P_1, P_2, \cdots P_n$ are unit prices or wages of material and labor entering sewer construction, and $Q_1, Q_2, \cdots Q_n$ are the quantities of material and labor required in constructing the project; "a" and "b" are, respectively, a specific time of construction, and the base period time of construction.

This is a fixed base, weighted cost index, and is believed to be a substantially accurate indicator of the purchasing power of funds invested in sewer construction. Reasons for selecting a fixed base, weighted index are outlined in part one of this pamphlet. The same factors apply to sewer construction.

Construction cost, as reported in the treatment plant index and as used in the sewer index, is equal to the sum of the following:

(1) Materials =concrete, lumber, iron, steel, etc., used in construction,

(2) Machines =process equipment and contractor's equipment used in construction,

(3) Men =skilled and common (heavy construction) labor employed during construction, and

(4) Money =overhead charged and profit earned during construction.

or

Construction cost $= M_1 + M_2 + M_3 + M_4$

Consideration was given the possibility of using parts of various general or special purpose construction cost indexes, such as those already mentioned (*2, 3, 4, 5, 6*) in the development of the sewer construction cost index. However, careful analysis of each brought out deficiencies, as pointed out, which proved to be too great to use for this purpose.

The construction described in this report is a statistically representative sewer installation project based on known quantities and costs, so that by using published price data available for the time period investigated, a responsive index reflecting the varying costs of sewer construction results.

This index, utilizing known quantities of labor and materials properly proportioned, has the advantage of being its own test for the base period. Because it has a fixed base, periodic surveys can be made to test whether or not the fixed base still reflects sewer construction practice. This method provides a yardstick to study the trends and magnitude of sewer project construction costs in constant dollar values. The two indexes—the Sewage Treatment Plant Construction Cost Index (WPC–STP) and the Sewer Construction Cost Index (WPC–S)—when used in conjunction, provide the tools necessary to equate sewerage projects, one to another, in both time and place.

assumptions and base data for index

The primary assumption is that this will be designed as a $1 million fixed base, weighted index, for a hypothetical sewer project. The

amount of $1 million was selected arbitrarily for convenience.

Other assumptions are as follows:

1. The hourly output of labor remains constant, in spite of changing wage rates.
2. Quantities and kinds of material used in construction remain constant and available during the period under study.
3. Modern construction techniques are employed over the entire period.

In view of these assumptions, the index may be used for: (*a*) estimating construction costs at various times, (*b*) checking present costs with costs for similar projects of previous years, (*c*) verifying other cost data, and (*d*) forecasting future cost trends.

Weighting

This index is not designed to reflect right-of-way or land, engineering, legal, or fiscal costs; nor does it allow for errors, omissions and changes occurring after a contract award. It does include: (*a*) material cost, (*b*) contractor's plant cost (contractor's equipment and supplies used in construction but not incorporated in the finished project), (*c*) labor cost, and (*d*) overhead and profit cost associated with the project. These correspond respectively to the: (*a*) materials, (*b*) machinery, (*c*) men, and (*d*) money previously cited.

Base Period

The base period for this index is the 36-month period January 1, 1957 through December 31, 1959. This period conforms to the postwar base period for federal index numbers as defined by the Bureau of the Budget.

Statistical Characteristics of Hypothetical Sewer Construction Project

An analysis of the construction contracts and bid documents for sewer projects assisted under the Federal Water Pollution Control Act for the period 1956 through 1962, after elimination of all lump sum type bids, revealed:

(1) Total number of projects	733
(2) Total contract dollar value	$75,259,681
(3) Total length of pipe	3,456,000 lin. ft.
(4) Range of pipe size	8 to 90 in.

Of the projects analyzed, more than 80 percent were for communities of 25,000 population and less; whereas, on a dollar basis, more than 40 percent of the funds were expended by cities with more than 25,000

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people. Geographically, these projects closely approximate the overall national distribution of projects and money in the sewer construction field. It is believed that this is a truly representative sample.

Further analysis disclosed that more than 90 percent of the projects included at least one bid item that was unique to the contract involved. Also more than 70 percent of the contracts had at least 65 bid items, excluding the pipe-in-place item. A multiplicity of items describing a single phase of construction calling for different materials, quantity units, and methods of installation also were observed. A typical example was the materials used in paving streets. These included chemicals, earth, crushed rock, sand and gravel, various classes of concrete, asphalt, etc. All such designated items have been grouped into a single construction category under "paving." Items such as lumber shoring, timber sheeting, steel sheeting, etc., whether left in place or removed, have been grouped into a single category, "sheeting and shoring." The eight categories found in table I represent the net result of such grouping of items or materials for a common purpose.

Table I.—Construction Categories and Costs for Sewer Construction, 1956–62*

Construction categories	Units	Total category cost	Average cost/unit	Percent of project cost
1. Paving	196,068 lin. ft	$662, 285. 19	$3. 377	. 88
2. Sheeting and shoring	4,083 Mbf	368, 772. 44	90. 319	. 49
3. Manholes	18,620 each	2, 521, 199. 32	135. 403	3. 35
4. Earth excavation	826,190 cu. yds	2, 220, 160. 59	2. 687	2. 95
5. Rock excavation	175,356 cu. yds	1, 377, 252. 16	8. 037	1. 83
6. Seeding and sodding	23,545 sq. yds	7, 525. 97	0. 319	. 01
7. Pipe in trench	3,456,162 lin. ft	35, 086, 063. 28	10. 152	46. 62
8. Lump sum items	L.S	33, 016, 422. 05		43. 87
Total sewer construction cost		75, 259, 681. 00		100. 00

* Analysis of projects assisted under the grants-in-aid program.

Table I presents the total number of units of material for each construction category, the total cost (contract) of each category, and the percent of total project costs represented by each category. For convenience, the average cost per unit was computed from the total costs and also is shown. Category 8 contains all the specially designed, unique, or one-of-a-kind type items such as inverted siphons, flow control devices, pumping stations less pumps, cutoff walls, etc. for which a lump sum price was given or could be assigned on the basis of all other prices being known.

The percent dollar distribution of these eight categories provided the basis for the hypothetical sewer construction project used in the development of the index. For convenience of data manipulation, a $1 million value was assigned to the hypothetical project. The percent of project cost when applied to the $1 million value produced the category costs for the hypothetical project. By using the average unit costs, the number of units for each construction category was obtained (table II).

development of cost index

Several steps are necessary to develop the cost index. First, the major construction categories must be determined. This was done and scaled down to a $1 million project, shown in table II. Next, it is necessary to determine unit costs assigned to the material, labor, contractor's plant, and overhead and profit for each construction category. These unit costs must then be reduced to quantities of selected materials, man-hours, and contractor's equipment rental hours.

Table II.—Construction Category Cost for a $1 Million Hypothetical Sewer Construction Project

Construction categories	Percent of project cost	Total category cost	Average cost/unit	Units
1. Paving	.88	$8,800.00	$3.377	2,605.86 lin. ft.
2. Sheeting and shoring	.49	4,900.00	90.319	54.25 Mbf.
3. Manholes	3.35	33,500.00	135.403	247.41 each.
4. Earth excavation	2.95	29,500.00	2.687	10,978.78 cu. yds.
5. Rock excavation	1.83	18,300.00	8.037	2,276.97 cu. yds.
6. Seeding and sodding	.01	100.00	0.319	313.48 sq. yds.
7. Pipe in trench	46.62	466,200.00	10.152	45,921.98 lin. ft.
8. Lump sum items	43.87	438,700.00	----------	
Total sewer construction cost	100.00	1,000,000.00	----------	

This procedure is highly complex because of the wide range of types of material, trades, construction rates, field conditions, construction methods, and procedures. For example, more than 40 identifiable trades were involved in the construction of the projects used in this study. The relative lack of cost data for contractor's plant and overhead and profit further complicated the procedure. Subsequently, this report clarifies the methods used to obtain these data.

After the quantities of material, labor, and equipment are established, they are combined with published price data for the selected areas of influence to obtain individual project costs for each area. Base period project costs are obtained in the same manner and cost indexes may then be computed. Details of these procedures follow.

Determination of Category Component Costs

To determine unit costs for the four components—material, labor, contractor's plant, and overhead and profit—the same procedure used in the *Sewage Treatment Plant Construction Cost Index* (7) was followed. Costs for material and labor were found to be available generally. Historically, contractor's equipment prices or costs normally have not been published or available. The WPC-STP was developed on the basis of costs occurring in the Kansas City, Mo. area. To place the WPC-S in the same frame of reference, and because the data were available for the Kansas City area, the hypothetical sewer project was developed using this restricted price data.

Therefore, the model project category cost components were determined on the basis of prices prevailing in the Kansas City, Mo. area during August 1962. These values for the entire project are included as appendix I. This procedure provided cost information for material, labor, and contractor's plant, and allowed the assignment of the balance of the total cost to overhead and profit.

To obtain the component costs for each category of construction for the model project, the units of material, labor hours, and contractor's plant rental time for each unit of construction had to be determined. Category 7 (pipe in trench) is used to illustrate how these determinations were made. First, however, it is necessary to delineate special problems encountered in determining pipe costs.

Special Factors Concerning Pipe. The range in pipe materials and sizes presented a major obstacle to development of the index. Continuous price data on the many sizes of pipe included in the basic study do not exist for the time period on which the index is based. However, when each type of pipe material was examined on a cost per diameter inch per foot of length basis, a constant differential in price between sizes evolved. This is graphically illustrated in figure 1 for reinforced concrete pipe, and mathematically presented in appendix J. It was not necessary to use the procedure for cast iron pipe since it is priced on a pound basis.

To estimate the cost of pipe of a size for which no information is published, it is necessary to know the cost of one size of pipe of the same material. The unknown pipe cost is approximately equal to the known pipe cost expressed in cost per diameter-inch per foot

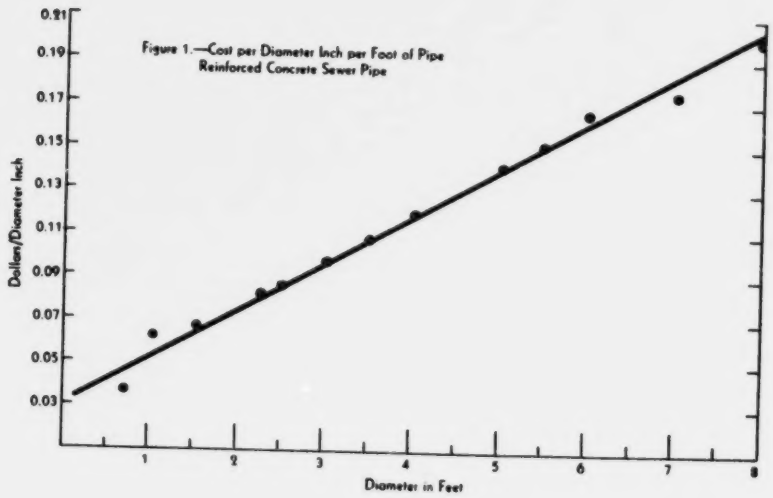


Figure 1.—Cost per Diameter Inch per Foot of Pipe Reinforced Concrete Sewer Pipe

plus the product of the difference in diameters and the slope of the curve (appendix J, part 2).

To further simplify index calculations, it was necessary to base pipe costs on equivalent pipe lengths. To arrive at such costs, the above procedure and the original pipe footage were used. Thus the pipe category calculations could be based on a single pipe price rather than a wide assortment of prices. To reduce the inherent bias caused by using the cost of a single size of pipe for this purpose, a composite pipe equal to the sum of the cost of both 12-in. and 24-in. pipe was used in the development of the index.

Distribution of costs for the various sewer pipe materials was based on the original projects studied under the grants-in-aid pro-

Table III.—Cost Distribution and Lengths of Various Pipe Materials

Material	Original study			Adjusted values		
	Size range (in.)	Scaled length* (ft.)	Percent of sewer cost	Composite size	Equivalent length (ft.)	Percent of sewer cost
Vitrified clay	8–36	21, 316. 98	30. 64	12–24 in.	10, 414. 37	32. 86
Concrete	8–96	18, 332. 05	56. 87	12–24 in.	24, 657. 70	60. 98
Cast iron	8–96	3, 085. 95	5. 75	49. 00 lb.	2, 156. 73	6. 16
Asbestos cement	8–36	3, 187. 00	6. 74			
Total		45, 921. 98	100. 00		37, 228. 80	100. 00

*Data scaled down for the $1 million hypothetical sewer project, from the original 733 projects.

gram. Lack of continuous price data on asbestos cement pipe for the historical period studied required an additional adjustment in the composite equivalent lengths of the other three materials evaluated to compensate for the exclusion of asbestos cement pipe in the index values. This adjustment was made on the basis of the costs of the other three materials and resulted in increases of 2.21 percent, 4.11 percent, and 41 percent respectively, for vitrified clay, concrete and cast iron.

Table III presents the original and adjusted cost distribution and equivalent lengths for the various types of sewer pipe within the size ranges studied.

Example of Computation for "Pipe in Trench" Category

In accordance with the general specifications of the projects reviewed "cost of sewer in trench" includes: (*a*) excavation, (*b*) cost of pipe, (*c*) placing and joining of the pipe, and (*d*) backfilling of the trench. Sheeting and shoring, gravel foundation, cradle or incasement of pipe, and surface restoration are excluded.

The pipe involved in the base contract information represents a wide range of sizes and types of material. To convert the linear feet of pipe to a material cost base required the development of a weighted unit price for each type material. This unit price was developed on the basis of the average unit cost of the original total pipe size, footage, and type of material. Table IV shows these unit prices for the various pipe materials, and the total material costs for the "pipe in trench" category of the hypothetical sewer project.

Table IV.—Material Cost Data for Category 7 "Pipe in Trench" of a Hypothetical $1 Million Sewer Construction Project

Type of material	Feet of pipe	Unit price	Material price
Vitrified clay	21, 316. 98	$1. 709	$36, 431
Concrete	18, 332. 05	3. 688	67, 609
Cast iron	3, 085. 95	2. 215	6, 835
Asbestos cement	3, 187. 00	2. 5122	8, 006
Totals	45, 921. 98	----------	118, 881

Because of the lack of historical price data, the material components for pipe in category 7 were then adjusted as previously discussed. The resulting material quantities and costs are given in appendix I.

Labor rates and costs were developed using certified payroll data to

determine the types of trades involved, their relative weight and average costs. These data, supplemented by information from *Building Construction Cost Data* (*8*), *Building and Public Works Administration, Estimating and Costing* (*9*), and "Relative Cost of Material and Labor—Construction of Water and Sewage Systems" (*10*), provide the basis for the labor distribution.

For category 7, the labor involved for the 45,922 ft. of pipe was:

	Hours	*Rate*	*Total*
Common labor	22, 492	$2. 88	$64, 777
Equipment operators	13, 950	3. 845	53, 638
			118, 415

The equipment cost component is based on known unit costs per hour of use from the Kansas City area, hours of use per linear footage of sewers installed and combinations of sizes and types of equipment in use, supplemented or extended by using *Compilation of Rental Rates for Construction Equipment* (*11*), *Contractor's Equipment Ownership Expenses* (*12*), and *Construction Planning, Equipment and Methods* (*13*). This approach was necessitated by the wide variety of sizes of pipe installed and materials excavated. In order to arrive at the unit cost per hour for equipment, the unit costs per hour from Kansas City for a variety of sizes of backhoes, cranes, drag lines, compressors, bulldozers, etc., were combined to obtain a weighted average unit cost. This was then extended by the equipment operator's time to obtain the category cost item.

Operating hours	*Cost/Hour*	*Total cost*
13,950	$10.7945	$150,583

Having established the cost items for materials, men, and machinery for the construction category, these were then subtracted from the total category cost to obtain the cost of the overhead and profit item.

Total category cost − (Material cost + Labor cost + Contractor's plant cost) = Overhead and profit cost.

For category 7, beginning with the total category cost from table II: $466,200 − ($118,881 + $118,415 + $150,583) = $78,321.

This procedure was applied to each of the construction categories and resulted in the cost values shown in table V.

Computation of Total Category Cost

Using the hypothetical sewer project category cost allocations, it then is convenient to express each component as a fixed percent of the total category cost. This makes it possible to use historically available published prices for material and labor to compute total

Table V.—Component Costs for the Construction Categories of a Hypothetical $1 Million Sewer Construction Project

Construction categories	Material	Labor	Contractor's plant	Overhead and profit	Totals
1. Paving	$2,516	$1,620	$3,784	$880	$8,800
2. Sheeting and shoring	1,750	1,142	1,428	580	4,900
3. Manholes	12,420	7,410	6,200	7,470	33,500
4. Earth excavation	0	8,500	12,740	8,260	29,500
5. Rock excavation	2,100	4,480	6,720	5,000	18,300
6. Seeding and sodding	21	53	21	5	100
7. Pipe in trench	118,881	118,415	150,583	78,321	466,200
8. Lump sum items	217,512	43,180	131,524	46,484	438,700
Totals	355,200	184,800	313,000	147,000	1,000,000

category costs. These percentages are shown in table VI and are based on the data in table V for the $1 million hypothetical sewer construction project. With this percent allocation, it is possible to compute the complete project breakdown for any situation where material and labor information is available.

Table VI.—Percentage Breakdown of Components of the Various Construction Categories of a Hypothetical $1 Million Sewer Construction Project

Construction categories	Component as percent of category cost				Category cost percent of total plant cost
	Material	Labor	Contractor's plant	Overhead and profit	
1. Paving	28.6	18.4	43.0	10.0	0.88
2. Sheeting and shoring	35.7	23.3	29.2	11.8	.49
3. Manholes	37.1	22.1	18.5	22.3	3.35
4. Earth excavation	0.0	28.8	43.2	28.0	2.95
5. Rock excavation	11.5	24.5	36.7	27.3	1.83
6. Seeding and sodding	21.0	53.0	21.0	5.0	.01
7. Pipe in trench	25.5	25.4	32.3	16.8	46.62
8. Lump sum items	49.6	9.8	30.0	10.6	43.87
Total	35.52	18.48	31.30	14.70	100.00

computation of national index

Calculating Total Prices

Unit prices for a given time period and location may now be multiplied by the total quantity factors given in appendix I to determine the total quantity costs for the material and labor for each category. The sum of these total quantity costs then represents the category cost in terms of material and labor. The combined material and labor costs then provide the basis to compute the contractor's plant cost, the overhead and profit cost, and thus the total category cost, using the cost relationships from table VI. This procedure was followed to calculate the value of each category over the entire period of the study. The sum of these total category costs for a given time period equals the total sewer project cost for that period.

Trade Area Cost Differences

Costs for materials and services vary markedly throughout the United States, with no apparent direct correlation, one to another. To reflect these cost variations, it is desirable to develop a number of indexes keyed to certain geographical areas of influence. In this way maximum use of the data can be made. Historically, 20 trade centers have been established and unit prices are reported regularly for them by *Engineering News-Record*. These 20 trade centers are:

Atlanta, Ga.	Dallas, Tex.	New York, N.Y.
Baltimore, Md.	Denver, Colo.	Philadelphia, Pa.
Birmingham, Ala.	Detroit, Mich.	Pittsburgh, Pa.
Boston, Mass.	Kansas City, Mo.	St. Louis, Mo.
Chicago, Ill.	Los Angeles, Calif.	San Francisco, Calif.
Cincinnati, Ohio	Minneapolis, Minn.	Seattle, Wash.
Cleveland, Ohio	New Orleans, La.	

Appendix A shows these 20 trade centers and their assigned areas of influence. The national index is based on the sum of the cost of identical projects priced for each of these areas.

Establishment of Base Period Cost

The base period cost for the index was computed by averaging the total project cost for each of the 20 trade centers on a monthly basis for the 36-months of 1957 through 1959. This base value was then equated to 100.

To compute the National Sewer Construction Cost Index for any time period, the average of the project costs for the 20 trade centers for that period is divided by the base value (appendix K) and multiplied by 100.

For example, the national index for August 1962 was computed as follows:

Average of 20 cities project cost for August 1962 = $1,010,487
Average of 20 cities project cost for base period = $920,969

$$\text{National index} = \frac{\$1,010,487}{\$920,969} \times 100 = 109.72$$

computation of individual city index

The Sewer Construction Cost Index for each of the 20 trade areas mentioned was determined by substituting the individual city project cost for the average city project cost in the index formula. Thus, the ratio of a particular city project cost to the base period project cost yields the city index. For example, the computation for Kansas City in August 1962 is as follows:

Kansas City project cost = $1,008,093
Base period project cost = $920,969

$$\text{Kansas City index} = \frac{\$1,008,093}{\$920,969} \times 100 = 109.46$$

Price data for each of the 20 cities for the month of August for the years 1930 through 1963 were obtained from *Engineering News-Record* (*6*) and the *BLS Wholesale Prices and Price Indexes* (*14*). In the event these sources did not cover the entire historical period, interpolation was used based on similarity of materials or trades at commencement of the series. This was done principally for labor trades in the early 1930's. Electronic data processing was used to manipulate all data and calculate the individual city indexes and the national index for each year.

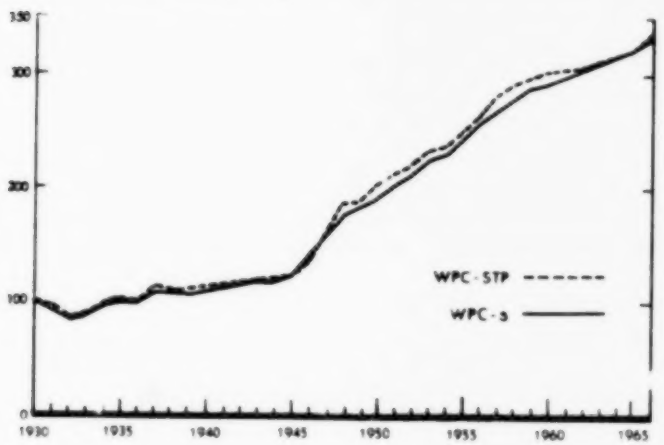
The indexes for each of the 20 cities, and the national index beginning in the year 1930 for the month of August are tabulated in appendix L and are shown graphically in appendix M. These indexes will be extended on a monthly basis from current price data published by *Engineering News-Record* (*6*) and BLS wholesale prices (*14*).

discussion

The WPCS Construction Cost Index is presented graphically in two forms for comparative purposes. The first shows the index (fig. 2) in comparison with the WPCSTP (*7*) and is plotted on the base of 1930=100. The second (fig. 3) shows the WPCS Index in comparison with the ENR Construction Cost Index (ENR-C) (*6*) and is again converted to the base 1930-100. The converted WPCS is tabulated in appendix L.

The WPC–S (fig. 2) increased slightly during the first 15 years of the study from an index value of 100 in 1930 to 123.51 in 1945. The postwar years, 1946 to 1948, comprised the period of maximum increase, in which the index rose almost 55 points in the 3 years. Over the next decade (1949–59) the index rose at an almost constant annual rate of 3.75 percent. From 1959 to 1966, the index continued to rise, but at a lesser annual rate fluctuating between 2 and 3 percent.

FIGURE 2 SEWAGE TREATMENT PLANT VS. SEWER CONSTRUCTION COST INDEXES 1930 = 100



During the early years and until the late fifties, the WPC–S closely follows the WPC–STP (fig. 2). However, from 1959 to 1964, the WPC–S index increased at a greater rate than the WPC–STP. This change in slope of the two indexes during that period was partially attributable to the continuing increase in pipe costs reflected in the WPC–S as compared to the static cost of concrete as reflected in the WPC–STP.

The difference between the WPC–S and the WPC–STP is best illustrated by a comparison of the percentage breakdown of their four major components of construction—material, labor, contractor's plant, and overhead and profit—as shown in table VII.

With the significant differences in material, labor, and contractor's plant shown in table VII, it is apparent that the two indexes can be influenced quite differently by changes in one or more of the many items that make up each.

Using the material component as an example, category 4, "Pipes, Valves, and Fittings" account for 10 percent of the material cost in the WPC–STP as compared to 33 percent of the similar category

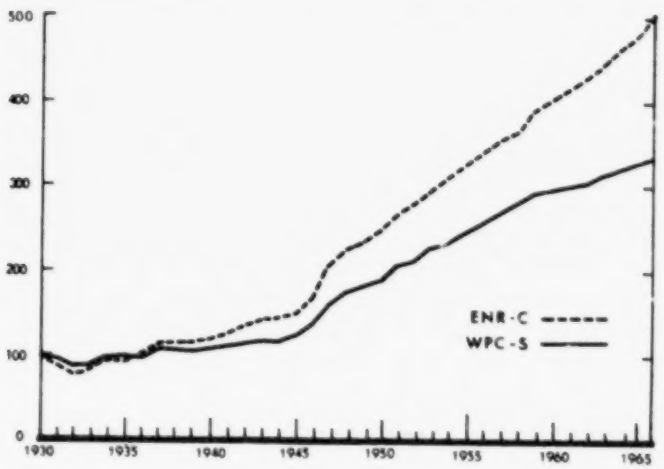
Table VII.—Major Components of Construction for Sewage Treatment Plants and Sewers

Items	Percent of total cost			
	Material	Labor	Contractor's plant	Overhead and profit
Sewage Treatment Plants (7)	54. 49	25. 33	6. 45	13. 73
Sewers	35. 52	18. 48	31. 30	14. 70

(category 7) "pipe in trench" in the WPC–S. Reducing these values by the percentages given in table VII shows that a shift in pipe costs will have over twice the effect on the WPC–S, as it will have on the WPC–STP. Similar variations are noted when comparisons are made for each item of material or labor that is involved in the two indexes.

Figure 3 shows that during the 1930's, the WPC–S and the ENR–C closely approximated each other. However, since the early 1940's the ENR–C has increased annually at a rate of one and a half times that of the WPC–S. Despite this varying rate, the two indexes closely approximate each other as to shift in slope and duration of trends until 1959. Since then, the ENR–C has increased at an annual rate of twice that of the WPC–S. This divergence between the two indexes has been caused primarily by the heavy reliance of the ENR–C on common labor prices which have risen about 5 percent per annum, whiles the WPC–S utilizes both skilled and common labor whose aggregate increase has been about 4 percent. Equating both indexes

FIGURE - 3 SEWER CONSTRUCTION COST INDEXES 1930 = 100



to 100 for 1930, the ENR–C has increased to 503.30, while the WPC–S has risen to 337.49 during the 36-year period studied.

The WPC–S was developed using price data from a selected area of the United States and consequently is biased toward this area. It is felt that the bias is minimal due to the close approximation of the average national data to the selected data used in the development of the index. The utilization of fixed percents for contractor's plant, and overhead and profit is also a limiting factor in use of the index. This factor precludes the index from responding to changing money market conditions and technical advances. Neither of these limitations is unique to this index, and it is believed that even with these restrictions the WPC–S is the most responsive index for the sewer construction field because of its reliance on information peculiar to sewer construction.

This index may be used to adjust sewer construction costs from one part of the country to another, as well as from one time period to another. This will further enable the application of past and current cost experience directly to new or proposed work of a similar nature in the same or other geographic locations.

The WPC–STP and the WPC–S complement each other and provide a more accurate means of adjusting and comparing prices in the sewerage field than would a single index. The inherent differences between sewer and plant construction preclude the use of a single index. Neither the WPC–STP nor the WPC–S is a valid substitute for the other.

To insure that the Sewer Construction Cost Index (WPC–S) continues to reflect current sewer construction practices and costs, re-evaluation of the index base will be undertaken periodically, and, if necessary, revisions or modifications of the index will be made

conclusions

1. A study of the various factors affecting the construction costs of sewers led to the development of a Sewer Construction Cost Index.

2. The study shows that the construction costs of sewers have increased steadily during the last 36 years.

3. This index may be used to evaluate past sewer construction activity and to estimate future sewer construction cost requirements for the 20 areas of influence in the United States and also for the Nation as a whole.

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appendices

appendix A

Map of 20 Index Cities and Their Assigned Areas of Influence

appendix B

Design Data for a 1.0-MGD High Rate Trickling Filter Plant

DESIGN SPECIFICATIONS

1. *Comminutor and Parshall Flume*

The comminutor structure and comminutor are sized for an average flow of 1.0 MGD and a maximum flow of 2.5 MGD. The channel of the comminutor structure is 1′3″ wide. With the use of stop plates, flow can be diverted either through the comminutor or a hand-cleaned bar screen.

The Parshall flume has a 12″ throat and is sized on the same basis as the comminutor. This is the only metering device used in the treatment plant.

2. *Preaeration Chamber*

The preaeration chamber includes two rectangular units with a combined detention time of 45 minutes based on a flow of 1.0 MGD. The inside dimensions of each chamber are 8′0″ wide, 26′0″ long, and a water depth of 11′0″.

Aeration is provided by blowers forcing air through diffusers. Each blower is sized to deliver 70 cfm of free air. This amount of air allows for 0.1 cubic foot per gallon of sewage based on a flow of 1.0 MGD. These blowers are sized so that one unit shall act as a standby.

Mechanical grit-collecting equipment provides for removal of collected grit and a manually operated skimmer is used to remove scum.

3. *Primary Sedimentation Tank*

This tank contains two parallel-operated, mechanically cleaned rectangular units, at design flow having combined rates of: surface settling rate, 1,000 gpd per square foot; detention time, 1.5 hours; weir rates, 10,000 gpd per linear foot.

The inside dimensions of each tank are 12′6″ wide, 40′0″ long, with an average water depth of 8′4″.

A manually operated skimmer is used to remove scum.

4. *Pumping Station*

The pumping station has three 1.0-MGD, constant speed, vertical turbine-type pumps which are located directly above the wet well. Space is provided for the installation of two additional pumps when required for plant expansion.

These pumps are automatically controlled by the levels of the sewage in the wet well using an air bubbler system, to maintain a flow of 3 MGD to the trickling filters, providing a recirculation ratio of from 1.5 to 1 to 0.2 to 1 as total plant flow varies. The pumps discharge through a 12" discharge line to the distribution box.

The wet well dimensions are 7'0" wide, 26'0" long, and the depth below the pump base is 14'0".

5. *Trickling Filter*

The trickling filters consist of two units. The hydraulic loading on each filter of 10 MGD based on a total plant flow of 1.5 MGD. Each unit has an inside diameter of 65'0" and the minimum filter media depth above the underdrains is 6'0".

For future needs, provision is made in the distribution box to service two additional filters.

The rotary distributor and jets for each filter are sized for a minimum rate of 520 gpm and a maximum rate of 870 gpm.

6. *Secondary Sedimentation Tank*

Secondary settling is provided by a single, mechanically cleaned, rectangular tank having a surface settling rate of 800 gpd per square foot. Weir rates, 10,000 gpd per linear foot. Design flow for this unit is 1.5 MGD.

This tank is 25'0" wide, 75'0" long, and has an average water depth of 8'0".

7. *Chlorine Contact Tank*

The rectangular chlorine contact tank has a detention time of 45 minutes based on a flow of 1.0 MGD. The tank dimensions are 16'6" wide, 26'0" long, and the average water depth 10'0". Wood baffles are placed to prevent currents and to allow for adequate mixing of the chlorine.

8. *Chlorinators*

Two automatically controlled, solution-fed chlorinators are provided. One chlorinator feeds the influent end of the aerated grit chamber and the other chlorinator feeds the chlorine contact tank. These chlorinators are located together in a well-ventilated building with automatic chlorine detection devices for safety purposes.

The chlorine storage building is equipped with a hoist and a hoist rail for unloading chlorine cylinders from a truck. This building has space available to store seven 1-ton cylinders.

9. *Digesters*

Two digesters are provided—one for primary, and one for secondary sludge. A structure, located between the digesters, houses the heat exchanger, motor control center, and sludge pumps.

The primary unit is 25′0″ inside diameter and has a capacity of 1.0 cubic feet per capita based on 10,000 population. This unit has a fixed cover and the sludge is heated and mixed with two draft-tube-type mixers.

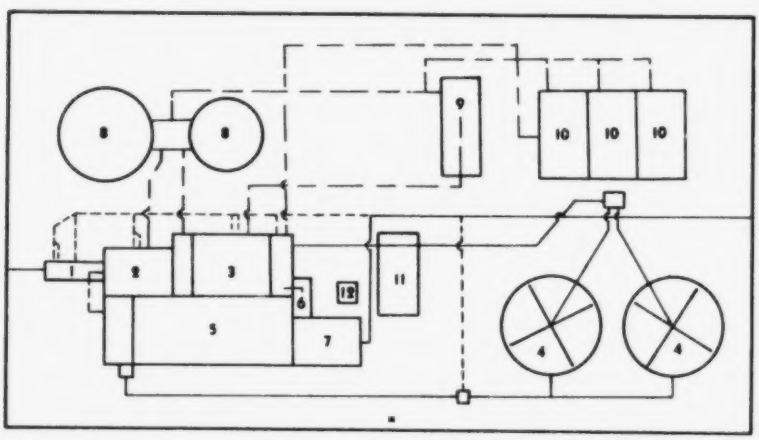
The secondary unit is 35′0″ inside diameter and has a capacity of 2.0 cubic feet per capita based on 10,000 population. This unit has a floating cover and the sludge is not mixed or heated.

10. *Sludge Filter Building*

This building contains a vacuum filter, chemical storage space, laboratory and office. The filter is designed for an allowable loading of 6 pounds dry solids per square foot per hour. Provision is made for conditioning chemicals.

11. *Sludge Drying Beds (Auxiliary)*

The drying beds consist of three underdrained rectangular units. Dimensions of each unit are 40′0″ wide, 60′0″ long, with earthen sides. These beds allow for a loading of 0.75 square foot per capita based on 10,000 population.



Plan View of the Federal Water Pollution Control Administration Index 1.0 MGD High Rate Trickling Filter Plant

1. Comminutor and Parshall flume
2. Preaeration Grit Chamber
3. Primary Settling Tank
4. High Rate Trickling Filter
5. Final Settling Tank
6. Recirculation Structure
7. Chlorine Contact Tank
8. Sludge Digesters
9. Sludge Filter Building
10. Sludge Drying Beds
11. Chlorine Storage Racks
12. Chlorination Building

appendix C

Material and Labor Cost Analysis of the Construction Categories

Category	Material			
	Components	Quantity	Unit cost	Item cost
Excavation and Fill	Rock (cu yd)	1, 559. 05	$2. 10	$3, 274. 00
	Earth and sand (cu yd)	2, 156. 31	1. 90	4, 096. 99
				7, 370. 99
Reinforced Concrete	Transit mixed concrete (cu yd)	1, 793. 42	13. 50	24, 211. 17
	Reinforcing steel (100 lbs)	2, 196. 15	7. 10	15, 592. 66
	Plyform (1,000 sq ft)	46. 30	205. 00	9, 491. 50
				49, 295. 33
Miscellaneous Iron and Steel	Structural shapes (100 lbs)	192. 21	10. 34	1, 987. 45
	Cast Iron (tons)	6. 88	138. 60	953. 57
	Reinforcing steel	507. 27	7. 10	3, 601. 62
				6, 542. 64
Piping, Valves, and Fittings	Cast Iron (tons)	127. 69	138. 60	17, 697. 83
	Vitrified clay pipe (ft)	747. 45	3. 751	2, 803. 68
	Reinforced concrete pipe (ft)	1, 952. 40	2. 94	5, 740. 06
				26, 241. 57
Process Equipment, Pumps and Motors	Structural steel shapes (100 lbs)	15, 392. 86	6. 167	94, 927. 77
	Pig iron, No. 2 Foundry tons)	356. 87	66. 50	23, 731. 86
				118, 659. 63
Sand and Rock	Crushed stone (tons)	3, 017. 14	2. 10	6, 335. 99
	Sand (tons)	267. 37	1. 90	508. 00
	Common brick (1,000)	61. 92	39. 00	2, 415. 19
				9, 259. 18
Buildings	Concrete block (each)	9, 883. 64	. 22	2, 174. 40
	Common brick (1,000)	28. 07	39. 00	1, 094. 73
	Structural steel (100 lbs)	280. 28	10. 34	2, 898. 10
				6, 167. 23
Other Items	Structural steel shapes (100 lbs)	3, 663. 50	6. 167	22, 592. 80
	Pig iron, No. 2 Foundry (tons)	84. 94	66. 50	5, 648. 51
				28, 241. 31
Total Plant				

for a 1.0-MGD High Rate Trickling Filter Plant at Kansas City, Mo.

August 1, 1962

Labor				
Class/Trade	Man-hours	Unit cost	Item cost	Category cost
Equipment operators	2, 040. 67	$3. 845	$7, 846. 38	
Common labor	1, 159. 05	2. 88	3, 338. 06	
			11, 184. 44	$18, 555. 43
Carpenters	2, 727. 80	3. 875	10, 570. 22	
Equipment operators	1, 054. 57	3. 845	4, 054. 82	
Ironworkers	1, 406. 57	4. 025	5, 661. 44	
Common labor	7, 483. 16	2. 88	21, 551. 50	
			41, 837. 98	91, 133. 31
Ironworkers	662. 61	4. 025	2, 667. 01	
Common labor	460. 43	2. 88	1, 326. 04	
			3, 993. 05	10, 535. 69
Ironworkers	2, 193. 20	4. 025	8, 827. 63	
Common labor	1, 535. 52	2. 88	4, 416. 54	
			13, 244. 17	39, 485. 74
Iron workers	1, 563. 30	4. 025	6, 292. 28	
Common labor	2, 818. 63	2. 88	8, 117. 65	
			14, 409. 93	133, 069. 56
Bricklayers	314. 46	4. 325	1, 360. 04	
Common labor	1, 135. 84	2. 88	3, 271. 22	
			4, 631. 26	13, 890. 44
Bricklayers	697. 11	4. 325	3, 015. 00	
Carpenters	361. 03	3. 875	1, 398. 99	
Common labor	735. 94	2. 88	2, 119. 51	
			6, 533. 50	12, 700. 73
Electrical workers	3, 108. 00	4. 50	13, 986. 00	
Common labor	2, 512. 41	2. 88	7, 235. 74	
			21, 221. 74	49, 463. 05
				368, 833. 85

appendix D

Total Plant and Category Costs for 20 Index Cities

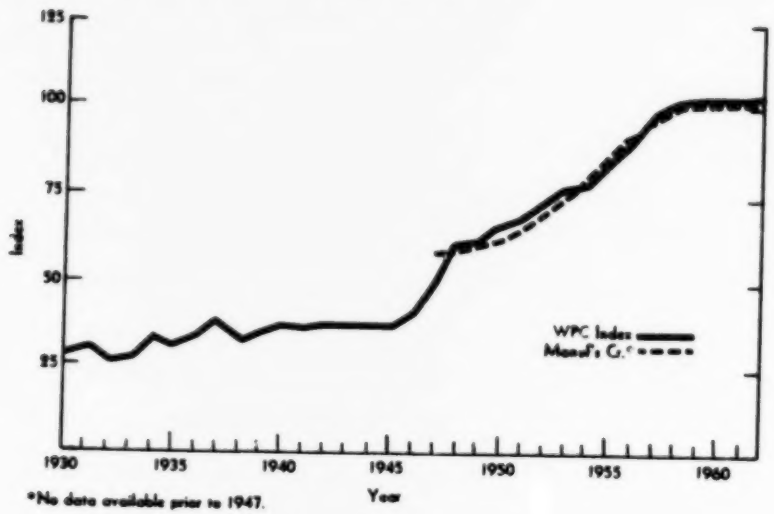
Cities	A Excavation and Fill	B Reinforced Concrete	C Miscellaneous Iron and Steel
Atlanta	$38, 968. 84	$102, 780. 01	$12, 279. 14
Baltimore	44, 987. 34	106, 917. 38	12, 864. 07
Birmingham	38, 346. 71	99, 453. 02	12, 088. 07
Boston	46, 405. 67	115, 605. 53	13, 222. 69
Chicago	47, 959. 21	112, 281. 77	12, 381. 49
Cincinnati	44, 215. 51	110, 280. 43	13, 083. 64
Cleveland	48, 986. 24	118, 404. 79	12, 309. 09
Dallas	38, 404. 74	96, 963. 79	12, 430. 90
Denver	33, 549. 13	101, 193. 47	12, 902. 00
Detroit	48, 214. 81	115, 094. 40	12, 605. 16
Kansas City	38, 064. 57	107, 001. 00	12, 359. 98
Los Angeles	44, 360. 65	107, 830. 16	12, 426. 52
Minneapolis	43, 582. 71	113, 942. 45	13, 145. 45
New Orleans	35, 781. 02	98, 666. 13	11, 623. 00
New York City	45, 979. 51	131, 252. 81	14, 074. 87
Philadelphia	45, 450. 78	113, 417. 21	13, 001. 86
Pittsburgh	46, 440. 61	113, 255. 40	12, 128. 17
St. Louis	44, 389. 23	111, 130. 01	12, 704. 97
San Francisco	41, 929. 21	113, 169. 69	13, 947. 90
Seattle	48, 924. 66	111, 937. 89	13, 290. 28

(Base period — 1957-59)

D Pipes, Valves, and Fittings	E Process Equipment Pumps and Motors	F Sand and Rock	G Buildings	H Other Items	T Total Plant
$39, 666. 30	$147, 551. 33	$15, 305. 22	$11, 181. 23	$50, 734. 54	$418, 466. 64
41, 768. 17	150, 111. 63	19, 042. 68	12, 204. 83	52, 238. 85	440, 134. 97
37, 536. 12	148, 125. 56	17, 351. 12	11, 246. 13	50, 814. 61	414, 961. 39
45, 383. 76	151, 738. 62	16, 103. 60	13, 452. 13	54, 348. 44	456, 260. 39
46, 665. 89	153, 025. 61	18, 910. 08	13, 719. 77	56, 203. 55	461, 147. 33
41, 437. 68	150, 980. 72	19, 570. 56	13, 116. 51	54, 408. 80	447, 090. 94
44, 081. 30	153, 034. 36	24, 476. 48	13, 917. 71	56, 210. 82	471, 420. 75
38, 758. 30	147, 754. 25	15, 956. 77	12, 438. 25	50, 561. 91	413, 268. 83
40, 988. 08	149, 278. 50	14, 565. 64	12, 452. 99	52, 520. 43	417, 450. 19
46, 008. 11	152, 870. 31	19, 989. 20	14, 225. 80	56, 794. 93	465, 802. 75
41, 105. 66	150, 132. 54	15, 774. 13	12, 762. 89	53, 611. 04	430, 811. 81
45, 822. 95	152, 130. 06	18, 094. 30	12, 572. 86	56, 138. 26	449. 375. 78
48, 644. 77	150, 786. 75	23, 192. 07	12, 833. 13	54, 083. 41	460, 210. 75
39, 564. 92	147, 840. 29	14, 034. 11	12, 692. 99	50, 913. 94	411, 116. 39
48, 053. 44	155, 340. 89	18, 160. 31	15, 652. 91	59, 108. 81	487, 623. 61
46, 040. 45	152, 377. 02	18, 481. 90	14, 024. 06	56, 138. 83	458, 932. 06
45, 219. 28	151, 609. 05	17, 325. 70	14, 084. 44	56, 792. 89	456, 855. 53
42, 366. 08	151, 559. 16	16, 154. 48	14, 132. 55	56, 237. 34	448, 673. 78
45, 715. 20	152, 116. 13	18, 002. 70	14, 287. 67	56, 149. 54	455, 318. 11
46, 582. 22	151, 738. 44	21, 618. 97	14, 260. 67	55, 182. 43	463, 535. 61

appendix E

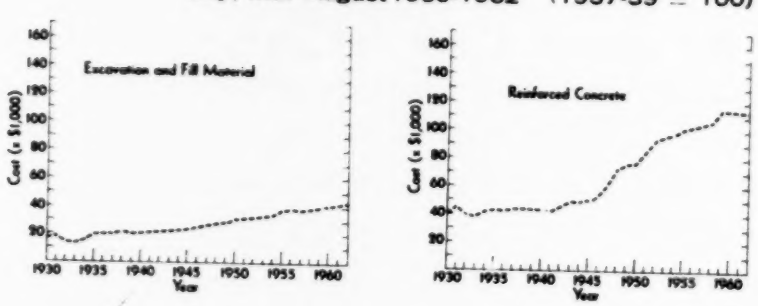
Sewage Treatment Plant Process Equipment — Manufacturers' Composite Experience Curve and FWPCA Process Equipment Index Curve (1957-59 = 100)

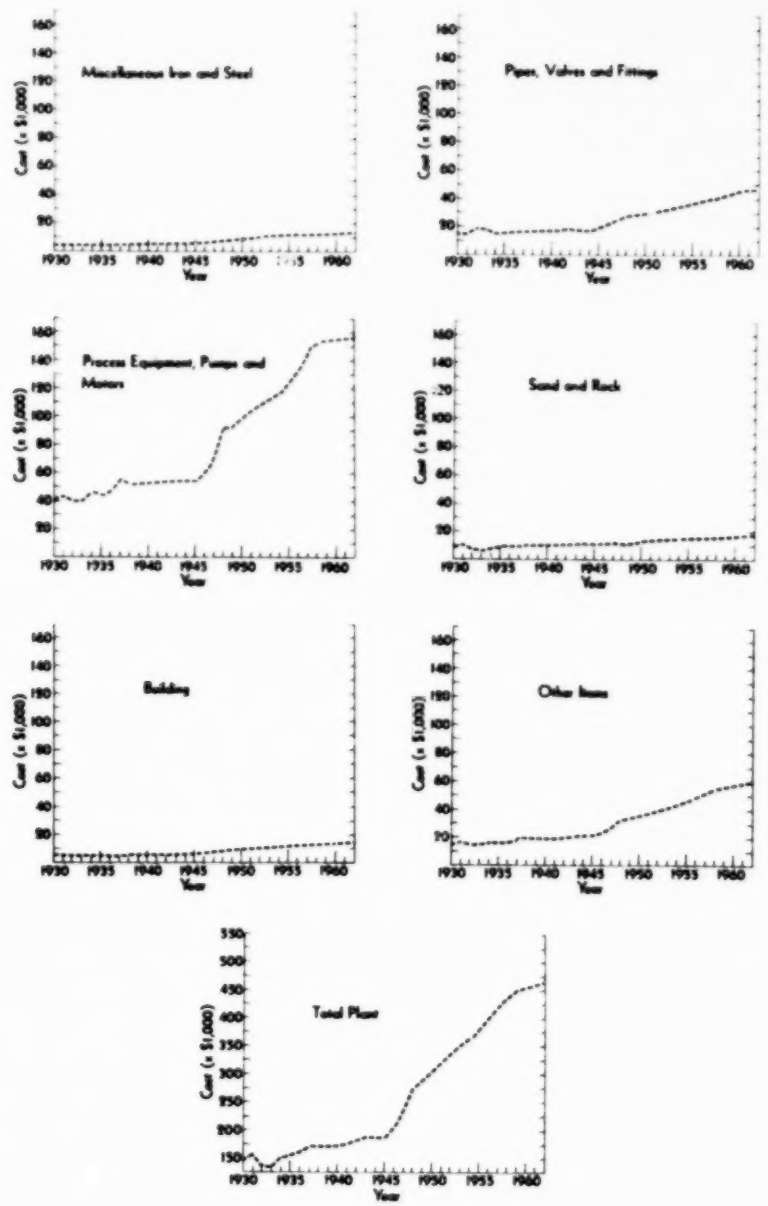


*No data available prior to 1947.

appendix F

Cost Curves by Category for a 1 MGD High Rate Trickling Filter Plant, Kansas City, Mo. August 1930-1962 (1957-59 = 100)




Miscellaneous Iron and Steel
Pipes, Valves and Fittings
Process Equipment, Pumps and Motors
Sand and Rock
Building
Other Items
Total Plant
Cost (x $1,000)
Year
1930
1935
1940
1945
1950
1955
1960

appendix G

Municipal Waste Treatment Plant Cost Indexes

Years	Atlanta	Baltimore	Birmingham	Boston	Chicago	Cincinnati	Cleveland	Dallas	Denver	Detroit	Kansas City
1930	29.37	34.02	32.37	34.33	37.26	36.00	39.06	35.24	37.51	31.86	32.45
1931	32.00	33.69	28.32	31.45	34.78	32.25	36.87	35.09	34.69	30.81	34.78
1932	31.25	32.53	27.33	31.42	32.81	31.22	31.26	30.24	31.31	29.07	30.35
1933	30.12	33.08	28.57	30.74	35.03	31.82	32.21	32.18	31.47	27.04	29.51
1934	33.43	35.17	30.12	33.79	36.75	34.00	37.10	33.72	35.30	30.78	33.53
1935	32.89	35.28	30.72	34.72	36.78	36.68	37.10	32.19	35.32	31.89	34.70
1936	34.19	35.74	32.31	34.58	37.08	35.06	37.66	33.03	35.24	32.35	35.82
1937	37.97	39.12	35.51	38.37	39.60	39.24	41.26	35.33	40.23	37.88	36.62
1938	36.45	37.95	33.64	37.16	39.95	37.24	39.32	35.45	39.03	35.82	38.24
1939	36.71	38.06	33.80	37.65	40.81	38.19	39.66	35.80	39.06	35.84	35.27
1940	37.37	38.59	34.44	38.54	40.75	39.24	40.04	36.55	39.44	36.45	38.47
1941	38.09	39.72	35.27	40.15	41.04	39.49	42.20	37.30	39.69	38.17	38.66
1942	38.31	40.55	38.30	41.99	42.21	40.19	41.99	40.79	39.09	40.01	39.82
1943	38.93	41.09	38.32	41.86	42.32	40.58	42.90	40.75	41.80	39.52	41.31
1944	39.00	41.20	38.32	42.68	42.31	40.78	43.90	41.37	41.46	41.00	41.34
1945	39.54	41.93	39.02	42.46	43.56	41.48	44.52	42.04	41.75	41.78	41.78
1946	45.94	47.19	43.87	46.69	47.26	46.14	50.14	46.54	46.52	46.52	46.39
1947	53.51	54.45	51.16	55.02	57.48	55.86	58.53	53.95	55.51	56.32	52.66
1948	61.06	63.69	59.92	66.27	66.38	66.44	67.04	62.69	63.55	65.64	62.20
1949	60.72	65.45	60.37	67.80	67.39	65.36	70.52	63.87	63.49	65.90	63.33
1950	64.91	69.41	63.37	71.22	70.39	69.07	74.33	68.15	67.58	72.06	68.25
1951	68.78	73.67	67.82	76.02	75.79	73.99	78.08	71.28	71.92	77.14	72.24
1952	71.08	76.48	71.10	78.47	78.96	77.22	83.11	72.61	73.68	80.42	76.08
1953	75.65	80.77	75.07	81.43	83.32	80.96	87.47	75.11	77.43	85.99	79.16
1954	76.45	82.02	76.31	84.10	85.59	83.41	89.14	76.74	78.53	88.10	81.24
1955	81.06	84.51	80.31	89.09	89.54	86.86	94.19	79.56	82.33	92.13	85.93
1956	86.48	89.30	85.08	94.76	95.92	92.17	99.18	84.53	86.15	97.66	90.08
1957	92.73	96.52	90.68	100.41	102.10	98.74	105.30	91.11	91.32	102.34	94.84
1958	96.05	100.08	93.75	103.36	104.50	102.15	107.04	93.64	94.10	105.65	97.70
1959	96.53	102.46	95.82	105.84	107.39	102.59	107.13	95.74	98.13	108.99	100.43
1960	97.71	103.29	98.08	106.88	107.51	104.73	108.71	96.64	99.43	109.88	101.72
1961	98.68	103.57	97.25	107.86	108.94	107.04	109.71	96.39	99.43	110.73	102.77
1962	100.31	105.19	96.86	108.27	109.41	107.54	110.62	97.22	101.16	111.70	103.49
1963	100.92	104.98	98.24	111.11	110.83	108.28	110.43	98.56	102.21	112.79	104.35
1964	103.63	104.54	99.70	112.48	113.12	110.86	113.28	100.12	104.90	114.57	105.87
1965	103.23	104.95	100.62	112.91	115.63	112.36	116.17	100.92	106.07	119.56	107.19
1966	105.88	113.15	104.17	116.97	120.31	115.50	120.25	105.19	109.39	122.56	111.69
1967	110.52	115.32	104.08	120.00	123.43	119.08	125.26	106.10	111.63	128.62	112.77

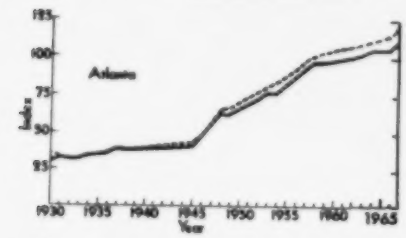
1930-67 August values (1957-59 = 100)

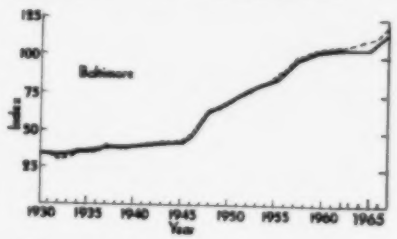
Los Angeles	Minneapolis	New Orleans	New York	Philadelphia	Pittsburgh	St. Louis	San Francisco	Seattle	National averages (1957-59 =100)	National average (1930 = 100)	Year
30.88	30.97	31.16	41.30	33.93	35.18	36.56	37.17	31.92	34.43	100.00	1930
31.41	29.40	28.59	38.18	31.96	33.92	37.04	35.64	31.47	33.12	96.18	1931
27.08	28.14	27.31	35.71	28.46	30.23	32.56	33.97	27.37	30.48	88.51	1932
29.89	28.62	29.09	36.72	29.27	29.17	32.51	34.85	27.71	30.98	89.96	1933
35.59	31.58	31.66	37.29	34.29	32.99	36.78	35.26	33.33	34.12	99.08	1934
34.86	31.46	32.19	35.81	35.84	32.80	33.86	35.30	33.35	34.19	99.28	1935
33.68	34.94	32.28	36.24	36.25	35.98	34.81	35.95	33.52	34.84	101.17	1936
37.28	40.13	35.54	41.00	39.76	42.76	39.91	40.41	40.07	39.00	113.25	1937
38.36	38.40	34.49	39.68	38.17	40.81	38.12	38.79	38.40	37.77	109.68	1938
35.91	38.66	34.46	39.82	39.05	41.11	38.15	38.85	38.49	37.92	110.12	1939
35.91	39.12	36.90	40.33	40.73	40.47	39.65	39.70	38.67	38.57	112.00	1940
36.46	39.67	37.35	41.24	41.30	41.57	40.51	40.57	39.69	39.41	114.44	1941
40.00	40.34	40.51	41.59	43.15	43.79	41.86	41.98	41.20	40.92	118.83	1942
40.19	40.11	39.28	41.64	43.22	43.44	42.24	43.68	43.50	41.23	119.73	1943
40.19	40.70	39.27	41.89	44.33	43.67	42.38	43.97	43.69	41.57	120.72	1944
40.42	41.52	41.38	43.09	45.40	44.49	43.53	43.18	45.12	42.40	123.13	1945
48.50	45.68	44.19	47.61	49.00	49.48	49.24	47.96	48.20	47.17	136.98	1946
54.26	55.58	51.39	57.57	59.93	58.60	57.22	56.70	56.54	55.61	161.49	1947
64.57	[illegible]	59.57	68.16	65.53	66.75	65.90	66.16	66.69	64.75	188.03	1948
65.42	[illegible]12	61.23	68.18	67.82	68.50	66.61	67.25	67.89	65.61	190.53	1949
69.76	[illegible]19	65.98	73.27	71.04	71.67	69.05	70.16	70.79	69.32	201.30	1950
73.03	74.67	69.13	77.51	77.52	75.50	74.49	74.24	75.57	73.92	214.66	1951
76.31	76.19	71.47	80.41	79.80	78.39	77.39	77.49	78.52	76.76	222.91	1952
80.92	81.58	74.71	84.80	84.52	83.66	81.40	80.97	80.50	80.77	234.55	1953
82.79	84.56	76.00	88.20	86.47	85.09	83.15	83.88	84.33	82.80	240.45	1954
87.01	88.89	79.89	92.68	91.44	89.26	94.17	88.11	87.67	87.23	253.31	1955
92.45	94.27	85.17	99.05	96.13	91.49	92.02	92.41	94.12	91.87	266.79	1956
98.45	99.84	90.15	106.31	100.39	100.93	97.93	100.01	100.88	98.04	284.71	1957
102.61	104.50	93.43	110.44	105.76	104.06	102.07	103.47	105.57	101.50	294.75	1958
105.66	107.71	95.20	114.78	103.85	107.30	104.92	104.68	107.86	103.65	301.00	1959
107.86	108.80	96.09	116.19	104.52	108.20	105.54	108.08	109.29	104.96	304.80	1960
108.53	109.93	97.41	118.39	105.62	107.81	106.28	108.65	111.63	105.82	307.33	1961
110.66	110.10	98.58	119.48	107.82	110.84	108.29	109.51	112.49	106.99	310.70	1962
111.72	111.67	99.76	121.46	109.14	112.39	109.92	116.50	115.08	108.52	315.14	1963
114.10	113.63	100.29	127.03	111.08	114.13	112.58	118.28	116.58	110.54	321.01	1964
116.64	115.62	102.67	131.41	112.77	115.84	114.70	123.18	118.99	112.57	326.91	1965
124.69	118.22	106.82	133.94	116.89	119.41	120.65	128.24	124.50	116.92	339.54	1966
128.03	122.17	109.59	139.02	119.07	121.35	125.84	133.24	130.51	120.28	349.29	1967

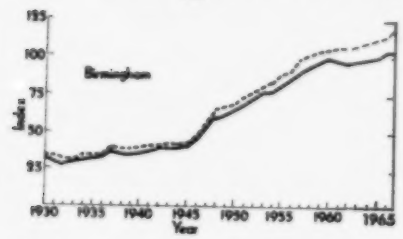
appendix H

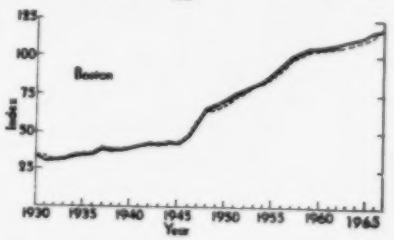
Individual City Indexes and National Index 1930-67

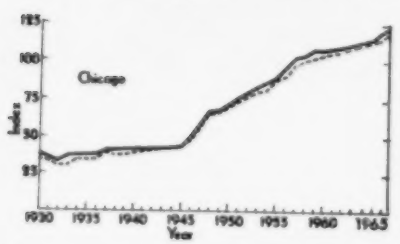
City Index ——— **National Index** - - - -

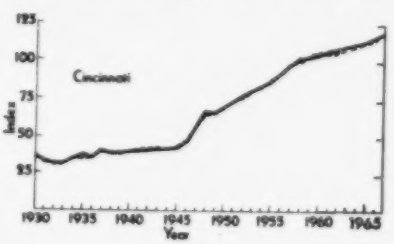


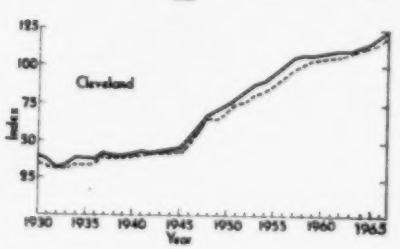


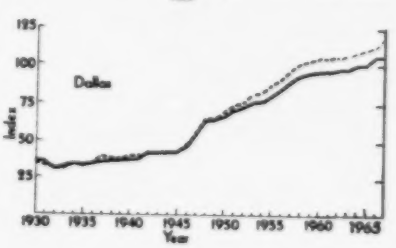


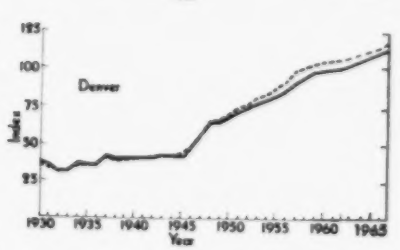


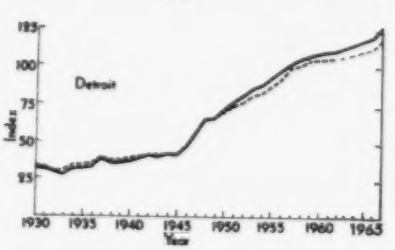


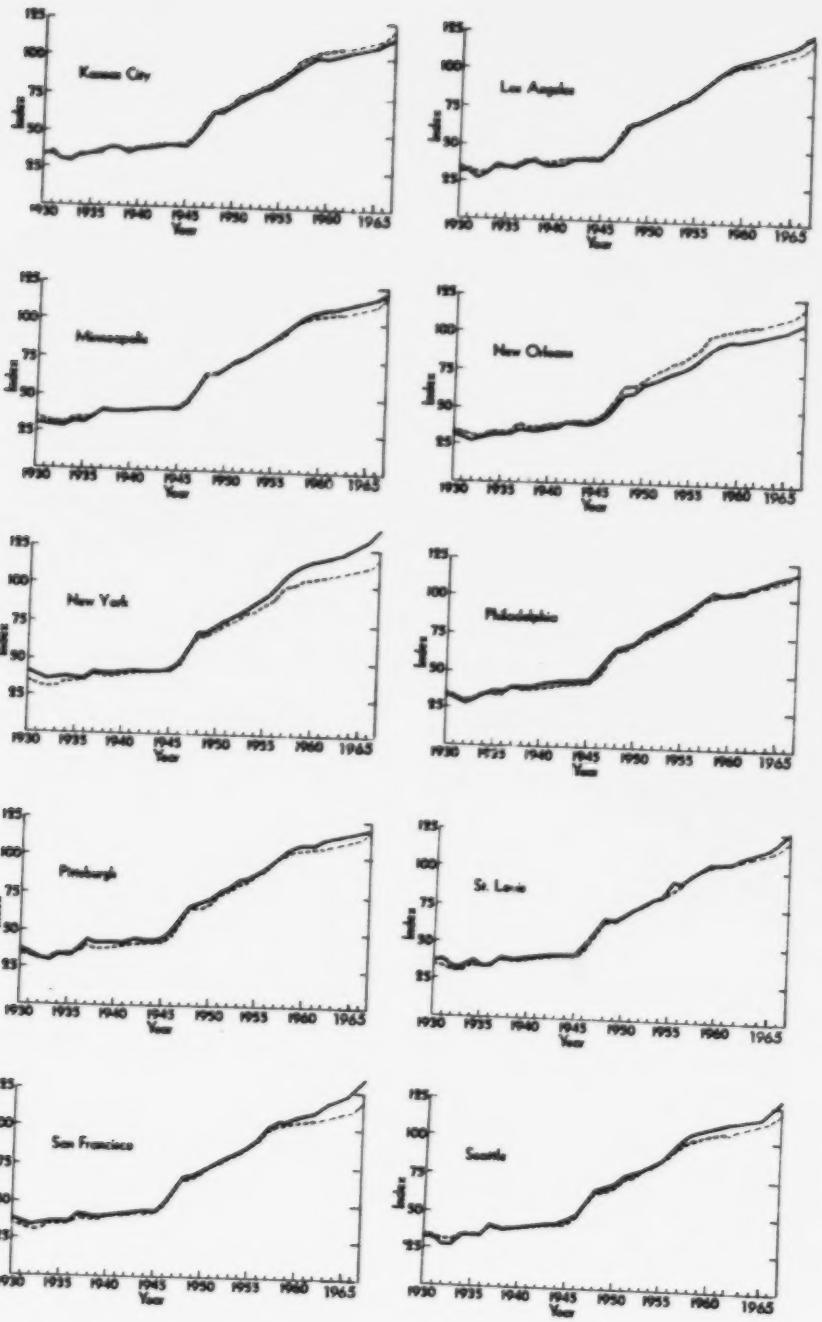











Kansas City
Los Angeles
Minneapolis
New Orleans
New York
Philadelphia
Pittsburgh
St. Louis
San Francisco
Seattle
Index
Year
1930
1935
1940
1945
1950
1955
1960
1965

appendix I

Material and Labor Costs Analysis of the Construction Categories

Category	Material			
	Components	Quantity	Unit cost	Item cost
1. Paving	Concrete (cu. yd.)	115.92	$13.50	$1,564.95
	Earth (cu. yd.)	278.08	1.90	528.36
	Rock (cu. yd.)	201.28	2.10	422.69
				2,516.00
2. Sheeting and shoring	Lumber (1,000 sq. ft.)	7.51	205.00	1,540.00
	Structural steel (100 lbs.)	8.46	10.34	87.50
	Structural shapes (100 lbs.)	19.86	6.17	122.50
				1,750.00
3. Manholes	Concrete (cu. yd.)	243.80	13.50	3,291.30
	Reinforced steel (100 lbs.)	297.38	7.10	2,111.40
	Plyform (1,000 sq. ft.)	6.24	205.00	1,279.26
	Cast iron (tons)	9.32	138.60	1,291.68
	Bricks (1,000)	75.79	39.00	2,955.96
	Concrete blocks (each)	6,774.55	.22	1,490.40
				12,420.00
4. Earth excavation				
5. Rock excavation	Gravel (cu. yd.)	1,000.00	2.10	2,100.00
				2,100.00
6. Seeding and sodding	Top soil (cu. yd.)	5.83	3.60	21.00
				21.00
7. Pipe in trench	Cast iron (tons)	52.84	138.60	7,323.07
	Vitrified clay pipe (lin. ft.)	10,414.37	3.751	39,064.30
	Concrete pipe (lin. ft.)	24,657.70	2.94	72,493.63
				118,881.00
8. Lump sum (other items)	Concrete (cu. yd.)	2,271.79	13.50	30,669.19
	Reinforced steel (100 lbs.)	2,787.83	7.10	19,793.59
	Plyform (1,000 sq. ft.)	58.36	205.00	11,963.16
	Structural shapes (100 lbs.)	11,674.97	10.34	120,719.16
	Cast iron (tons)	216.57	138.60	30,016.66
	Structural steel shapes (100 lbs.)	387.97	6.167	2,392.63
	Pig iron (tons)	29.44	66.50	1,957.61
				217,512.00
Total project				355,200.00

for a $1 Million Hypothetical Sewer Project at Kansas City, Mo.

August 1, 1962

Labor*				Category cost
Class/Trade	Man-hours	Unit cost	Item cost	
Equipment operators	350.54	$3.845	$1,347.83	
Carpenters	41.81	3.875	162.00	
Common labor	38.25	2.88	110.17	
			1,620.00	$4,136.00
Carpenters	185.67	3.875	719.46	
Ironworkers	60.69	4.025	244.30	
Common labor	61.89	2.88	178.24	
			1,142.00	2,892.00
Equipment operators	507.67	3.845	1,951.99	
Carpenters	24.38	3.875	94.47	
Ironworkers	55.43	4.025	223.11	
Bricklayers	1,156.07	4.325	5,000.00	
Common labor	48.76	2.88	140.43	
			7,410.00	19,830.00
Equipment operators	1,180.22	3.845	4,537.94	
Common labor	1,375.71	2.88	3,962.06	
			8,500.00	8,500.00
Equipment operators	622.53	3.845	2,393.63	
Common labor	724.43	2.88	2,086.37	
			4,480.00	6,580.00
Equipment operators	5.83	3.845	22.42	
Common labor	10.62	2.88	30.58	
			53.00	74.00
Equipment operators	13,950.00	3.845	53,638.00	
Common labor	22,492.00	2.88	64,777.00	
			118,415.00	237,296.00
Equipment operators	2,184.25	3.845	8,398.44	
Carpenters	4,522.33	3.875	17,524.03	
Ironworkers	206.86	4.025	832.61	
Electricians	88.89	4.50	400.00	
Common labor	5,564.21	2.88	16,024.92	
			43,180.00	280,692.00
			184,800.00	540,000.00

appendix J

Sewer Pipe Cost Relationships

Part 1

An analysis of the cost per diameter inch per foot of pipe over a period of years disclosed that there was a constant differential between pipes of varying diameter. Using this constant differential, the statistical method of "least squares" was used to determine the best fitting linear curve. The straight line appearing in figure I had the form of $y=a+bx$ in which y is the cost and x is the diameter of the pipe, based upon the following data:

Reinforced Concrete Sewer Pipe—Kansas City, Mo., Aug. 1, 1962

Diameter of pipe in ft.	Cost/ft. of length	Cost/diameter in/ft. of length
0. 67	$0. 296	$0. 037
1. 00	. 744	. 062
1. 50	1. 188	. 066
2. 00	1. 752	. 073
2. 25	2. 214	. 082
2. 50	2. 580	. 086
3. 00	3. 492	. 097
3. 50	4. 536	. 108
4. 00	5. 712	. 119
4. 50	6. 966	. 129
5. 00	8. 460	. 141
5. 50	9. 966	. 151
6. 00	11. 952	. 166
7. 00	14. 784	. 176
8. 00	19. 488	. 203

The resultant equation for reinforced concrete pipe is $y= .032066+ .021368x$.

Part 2

Example: Estimating Pipe Cost

Using the cost of a known diameter of pipe, the estimated cost of a second size pipe is determined by solving the following equation:

$$y_2 = y_1 + b(x_1 - x_2)$$

in which y_2 = unknown pipe cost

y_1 = cost of pipe known

$b = .021368$

$x_1 - x_2$ = difference in diameter between pipes in feet.

To estimate the cost of 60-inch pipe with the cost of 24-inch pipe known the following calculations result. Using the cost for 24-inch pipe given in the tabulation of $0.073 per diameter-inch:

$y_2 = .073 + .021368(5-2)$

$y_2 = .073 + .064104$

$y_2 = .137$ (which is $\pm$ 3 percent of the actual value)

appendix K

Total Sewer Project Costs for 20 Index Cities

Cities	Paving	Sheeting and shoring	Manholes
1. Atlanta	$7,325.96	$4,079.23	$27,888.61
2. Baltimore	7,647.42	4,258.22	29,112.35
3. Birmingham	6,739.46	3,752.65	25,655.88
4. Boston	8,583.99	4,779.72	32,677.68
5. Chicago	8,771.42	4,884.09	33,391.21
6. Cincinnati	7,795.24	4,340.53	29,675.04
7. Cleveland	8,336.29	4,641.80	31,734.72
8. Dallas	7,020.81	3,909.31	26,726.94
9. Denver	7,172.90	3,994.00	27,305.91
10. Detroit	8,759.58	4,877.50	33,346.15
11. Kansas City	7,762.79	4,322.46	29,551.52
12. Los Angeles	8,272.57	4,606.32	31,492.18
13. Minneapolis	8,993.24	5,007.60	34,235.62
14. New Orleans	7,215.81	4,017.89	27,469.26
15. New York	9,620.53	5,356.89	36,623.62
16. Philadelphia	8,429.68	4,693.80	32,090.26
17. Pittsburgh	8,279.82	4,610.35	31,519.76
18. St. Louis	7,989.27	4,448.57	30,413.71
19. San Francisco	8,510.80	4,738.97	32,399.07
20. Seattle	8,863.00	4,935.08	33,739.81

(Base period — 1957-59)

Earth excavation	Rock excavation	Seeding and sodding	Pipe in trench	Lump sum items	Total plant cost
$24, 558. 63	$15, 234. 67	$83. 25	$388, 109. 57	$365, 215. 94	$832, 495. 86
25, 636. 25	15, 903. 17	86. 90	405, 139. 70	381, 241. 52	869, 025. 53
22, 592. 49	14, 015. 00	76. 58	357. 037. 99	335. 977. 20	765. 847. 25
28, 775. 87	17, 850. 79	97. 55	454, 756. 23	427, 931. 25	975, 453. 08
29, 404. 20	18, 240. 60	99. 68	464, 685. 99	437, 275. 25	996, 752. 44
26, 131. 76	16, 210. 55	88. 58	412, 970. 32	388, 610. 20	885, 822. 22
27, 945. 50	17, 335. 68	94. 73	441, 633. 68	415, 582. 79	947, 305. 19
23, 535. 66	14, 600. 09	79. 78	371, 943. 26	350, 003. 23	797, 819. 08
24, 045. 51	14, 916. 36	81. 51	380, 000. 51	357, 585. 21	815, 101. 91
29, 364. 52	18, 215. 95	99. 54	464, 058. 91	436, 685. 21	995, 407. 36
26, 022. 98	16, 143. 07	88. 21	411, 251. 26	386, 992. 54	882, 134. 83
27, 731. 92	17, 203. 19	94. 01	438, 258. 31	412, 406. 52	940, 065. 02
30, 147. 79	18, 701. 85	102. 20	476, 437. 21	448, 333. 32	1, 021, 958. 83
24, 189. 35	15, 005. 60	82. 00	382, 273. 69	359, 724. 28	819, 977. 88
32, 250. 65	20, 006. 34	109. 32	509, 669. 69	479, 605. 54	1, 093, 242. 58
28, 258. 59	17, 529. 90	95. 79	446, 581. 49	420, 238. 74	957, 918. 25
27, 756. 20	17, 218. 25	94. 09	438, 642. 10	412, 767. 68	940, 888. 25
26, 782. 22	16, 614. 06	90. 79	423, 249. 86	398, 283. 38	907, 871. 86
28, 530. 53	17, 698. 60	96. 72	450, 879. 02	424, 282. 76	967, 136. 47
29. 711. 18	18, 431. 00	100. 72	469, 537. 35	441, 840. 49	1, 007, 158. 63

appendix L

Sewer Construction Cost Indexes, 1930-67,

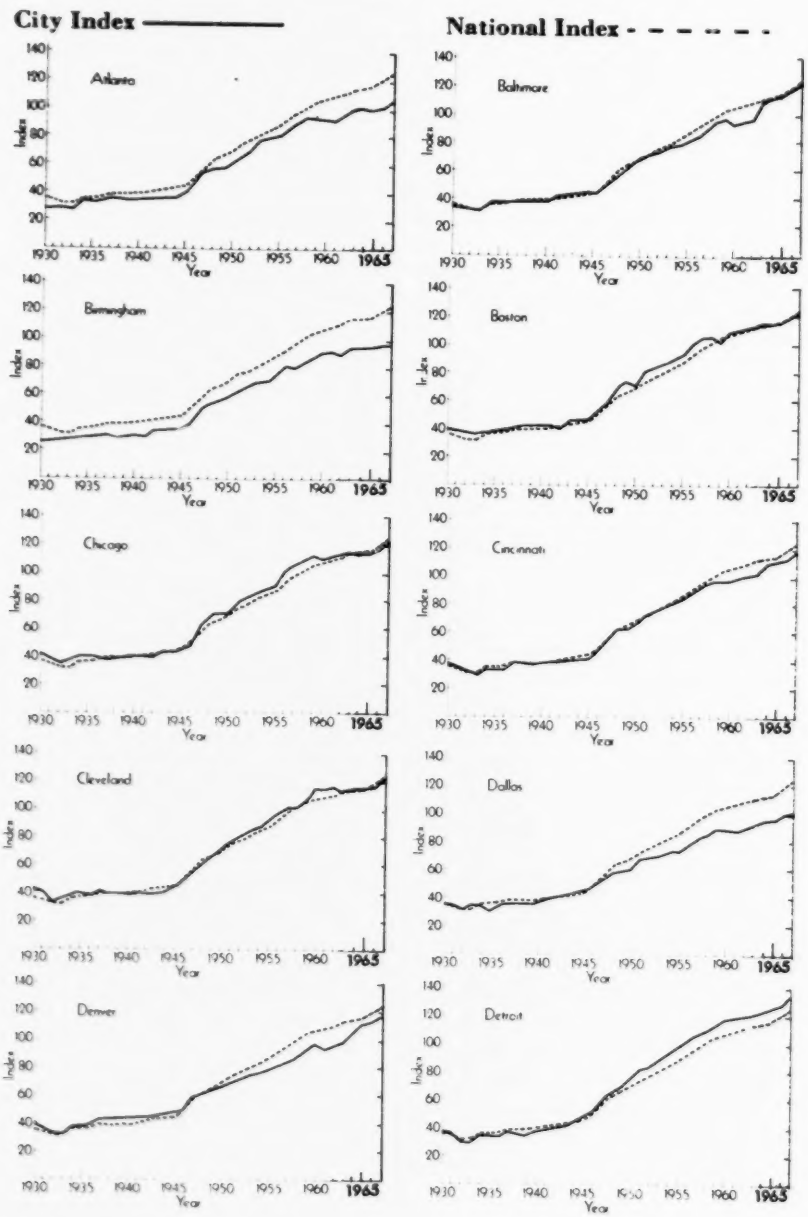
Years	Atlanta 1	Baltimore 2	Birmingham 3	Boston 4	Chicago 5	Cincinnati 6	Cleveland 7	Dallas 8	Denver 9	Detroit 10	Kansas City 11
1930	28.48	32.73	34.87	38.41	40.97	36.43	41.62	39.16	38.08	36.45	33.41
1931	27.72	32.14	25.69	36.42	37.97	33.53	39.96	33.86	35.36	35.82	36.54
1932	27.93	31.49	26.47	35.80	34.07	31.74	31.21	30.41	31.90	29.95	33.37
1933	27.79	31.86	27.69	34.93	36.48	29.13	34.23	34.81	31.87	28.45	32.66
1934	33.57	36.77	28.14	35.86	39.86	33.53	38.48	34.03	[illegible]	34.29	36.43
1935	32.45	37.20	29.01	36.69	39.91	33.52	38.39	30.24	36.60	33.06	36.93
1936	33.73	36.08	29.42	37.71	38.00	33.22	36.72	34.74	38.44	32.97	37.26
1937	36.00	38.51	30.85	40.80	37.32	39.50	40.25	35.11	42.83	37.55	38.76
1938	34.56	39.03	29.69	42.15	38.76	37.21	37.63	35.22	42.41	34.78	39.37
1939	32.91	38.19	29.74	41.01	39.45	37.72	38.48	35.01	42.64	34.33	39.42
1940	33.67	39.15	30.58	41.11	39.34	39.48	38.18	36.43	43.03	37.59	39.30
1941	34.14	42.22	30.95	40.96	39.48	39.13	39.89	40.71	43.15	39.14	39.58
1942	34.26	42.14	34.63	39.67	39.10	39.87	38.44	41.43	43.16	40.28	40.40
1943	35.11	45.15	34.81	44.61	43.07	40.44	39.32	42.89	45.50	41.12	42.45
1944	35.15	43.58	34.81	45.70	43.07	41.02	41.29	43.66	46.10	43.90	43.98
1945	38.51	44.59	35.39	45.03	44.30	41.59	43.85	44.37	46.32	45.58	43.54
1946	48.30	49.42	39.33	50.68	48.86	48.93	48.68	49.53	49.91	50.02	47.16
1947	53.42	53.32	48.90	58.28	61.42	56.48	56.96	55.05	58.47	58.42	51.99
1948	56.75	59.90	53.52	69.88	68.20	63.35	62.09	58.62	63.83	65.47	59.88
1949	56.51	65.66	55.78	73.23	70.17	62.69	66.89	60.00	64.22	67.54	62.78
1950	60.50	68.20	57.61	70.19	70.46	67.19	71.30	61.41	67.01	75.21	65.56
1951	64.32	72.80	62.40	81.65	78.27	73.47	75.44	69.18	71.19	80.32	69.88
1952	69.02	74.39	65.20	83.63	81.92	75.38	80.55	69.38	71.73	82.07	73.73
1953	76.82	79.18	67.97	86.68	85.63	80.08	84.46	71.21	75.67	89.07	76.84
1954	77.82	79.86	68.86	90.31	87.66	82.40	86.79	73.40	76.73	92.18	81.43
1955	80.25	82.02	72.80	93.23	91.66	85.64	92.98	74.32	79.88	96.99	85.88
1956	86.95	85.28	80.07	101.24	102.01	90.94	96.48	78.60	82.51	102.53	88.99
1957	90.70	91.60	79.99	105.17	107.07	94.40	101.05	83.81	85.65	105.24	91.48
1958	93.51	96.13	82.12	106.60	108.35	97.18	102.15	86.24	87.23	108.69	96.02
1959	92.57	98.41	86.30	103.25	112.15	97.79	106.58	91.28	94.14	112.40	100.88
1960	92.01	94.05	90.37	109.02	109.72	97.90	114.50	90.39	97.09	116.94	105.14
1961	91.59	95.50	90.67	110.60	111.56	101.35	113.47	90.05	94.13	118.18	107.71
1962	95.56	96.75	89.23	111.03	112.38	101.85	114.97	91.57	96.55	119.22	109.46
1963	98.71	110.58	92.65	117.07	114.98	103.51	111.96	93.98	99.01	121.11	110.95
1964	103.58	114.80	94.03	114.44	111.83	110.06	115.39	95.12	106.61	122.82	110.06
1965	101.83	115.19	94.98	115.83	113.89	111.82	118.21	96.04	111.08	126.82	111.59
1966	103.44	119.70	97.34	119.30	118.05	114.32	117.02	100.27	112.88	127.60	115.70
1967	108.40	123.37	97.71	124.53	121.27	118.95	125.43	102.01	117.40	134.84	117.88

August values (1957-59 = 100)

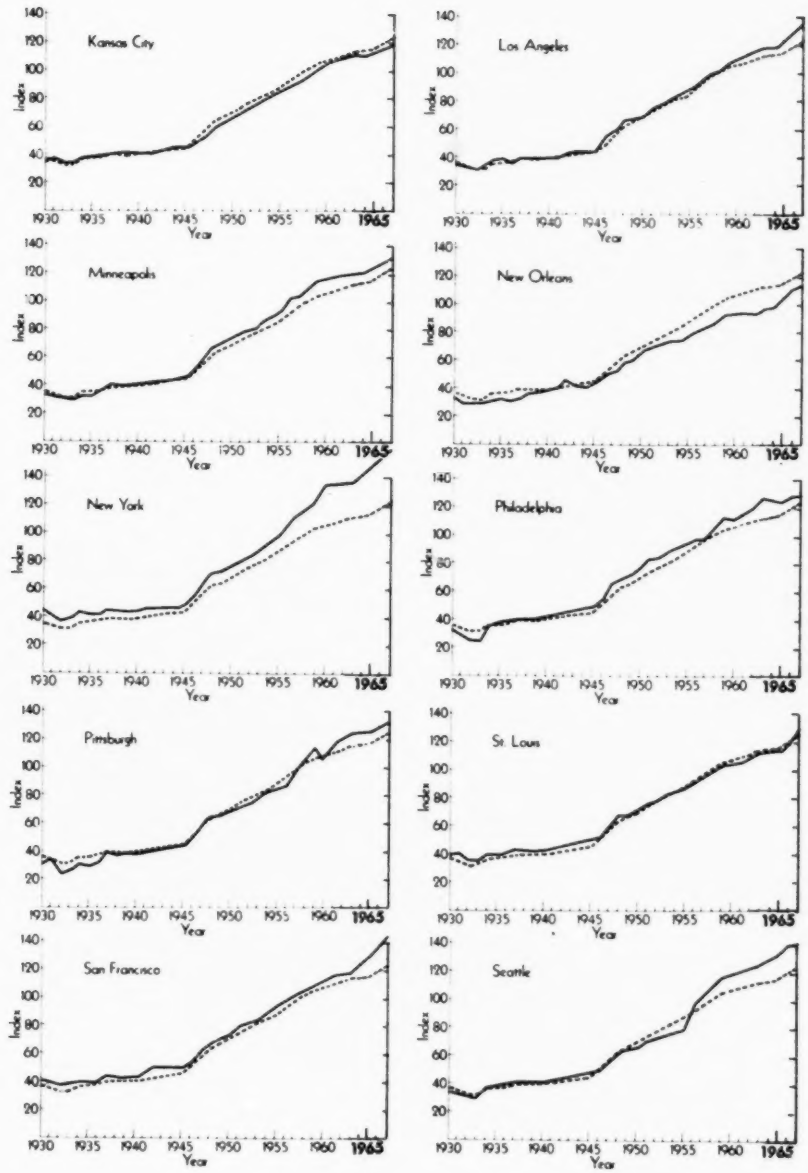
Los Angeles 12	Minneapolis 13	New Orleans 14	New York 15	Philadelphia 16	Pittsburgh 17	St. Louis 18	San Francisco 19	Seattle 20	National averages (1957-59=100)	National index (1930=100)	Years
34.10	33.28	32.52	43.87	31.07	31.38	38.41	39.67	33.18	35.90	100.00	1930
32.07	31.88	28.74	39.87	27.49	34.53	39.64	38.63	31.49	34.01	94.72	1931
30.64	30.64	28.31	36.43	23.60	24.41	34.19	35.31	29.56	30.87	85.97	1932
33.49	29.98	29.19	38.54	23.98	25.06	33.93	35.95	29.12	31.46	87.62	1933
37.68	32.76	30.41	42.89	34.59	30.58	39.75	37.75	36.89	35.54	98.98	1934
38.03	31.82	31.93	40.55	36.94	29.84	38.07	37.80	38.70	35.35	98.45	1935
35.90	36.38	30.98	41.06	37.35	32.27	38.45	37.65	39.35	35.88	99.93	1936
39.93	40.47	32.41	45.06	39.67	38.33	42.18	42.67	40.80	38.95	108.48	1937
39.92	39.95	35.92	43.89	39.12	37.13	41.27	42.19	39.74	38.50	107.22	1938
39.01	40.14	35.51	43.04	38.21	38.39	41.23	41.83	39.67	38.30	106.67	1939
39.21	40.37	39.21	43.31	41.29	37.73	41.06	42.30	39.61	39.10	108.89	1940
39.62	41.03	39.34	45.42	41.97	38.43	42.88	45.41	40.07	40.18	111.90	1941
42.84	43.26	45.48	45.66	43.37	40.61	44.47	48.97	42.98	41.55	115.72	1942
43.13	43.20	41.61	45.02	44.45	41.58	46.65	47.81	44.98	42.54	118.47	1943
43.13	43.76	41.32	45.39	46.32	42.69	47.50	48.14	45.08	43.28	117.75	1944
44.83	45.00	43.12	47.53	47.82	43.51	47.74	48.23	46.05	44.35	123.51	1945
58.17	50.40	48.64	53.66	53.31	49.21	51.13	52.30	48.23	49.64	138.25	1946
59.56	60.50	51.12	64.60	64.51	58.33	59.39	60.88	54.98	57.33	159.66	1947
65.63	68.66	56.51	72.43	67.79	62.90	66.98	66.61	63.00	63.60	177.13	1948
67.00	70.13	59.59	72.82	71.06	63.90	66.96	69.96	64.32	65.57	182.61	1949
68.83	73.36	65.48	77.36	75.07	68.03	69.45	72.18	65.74	68.51	190.80	1950
75.16	79.33	69.13	80.87	82.94	70.66	74.56	79.09	70.12	74.04	206.20	1951
77.56	80.05	71.01	84.38	82.57	73.08	76.40	82.35	72.24	76.33	212.58	1952
83.69	86.65	73.94	89.76	88.70	78.68	80.59	82.90	73.83	80.62	224.53	1953
86.73	89.26	74.46	93.79	90.51	81.79	83.59	88.40	76.52	83.12	231.49	1954
89.91	93.51	77.56	98.59	94.49	84.60	86.87	94.06	78.90	86.71	241.49	1955
94.01	103.54	81.39	108.93	96.98	85.49	90.89	97.29	96.44	92.48	257.56	1956
100.42	104.57	84.79	114.40	98.10	97.25	95.09	102.86	102.43	98.80	269.59	1957
101.98	111.28	88.07	119.81	106.25	101.58	98.28	105.29	111.59	100.42	279.67	1958
108.37	116.97	93.72	123.74	112.81	114.26	104.44	108.62	116.98	104.78	291.81	1959
110.86	117.83	93.24	135.25	111.93	104.48	104.40	112.18	117.18	106.22	295.82	1960
114.95	119.58	94.78	137.64	115.82	114.06	108.09	115.30	120.85	108.19	301.31	1961
117.38	120.04	93.83	137.68	119.63	120.41	108.50	116.00	122.55	109.72	305.57	1962
118.99	120.49	96.47	138.58	126.30	122.58	110.88	127.37	125.14	113.07	314.90	1963
119.19	120.48	98.60	144.73	126.46	123.92	113.63	126.94	129.31	115.10	320.55	1964
123.19	122.77	103.51	149.92	123.93	126.40	115.92	131.93	131.30	117.31	326.71	1965
131.24	126.22	110.99	154.81	127.90	129.76	119.80	138.18	139.14	121.18	337.49	1966
134.08	131.05	114.45	159.30	130.82	131.96	128.33	143.74	141.70	125.36	349.13	1967

appendix M

Individual City Indexes and National Index



1930-67



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